DISTRIBUTED COMPUTING, P. 36

IEEE
SPECTRUM

HIGH ON LOW VOLTAGE

MAY 1992 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Newslog

MAR 11. IBM Corp. said it would set up an independent subsidiary to sell an inexpensive clone of its PCs in Europe. The IBM name or logo will not be used on the machine. Last October IBM set up a similar venture with **Hong Leong Corp.**, a trading company in Singapore, which has begun selling a low-end IBM PC in Southeast Asia.

MAR 11. Micron Technology Inc., Boise, Idaho, the 10th largest U.S. semiconductor producer, said it had written to U.S. industry executives, urging support for a congressional bill proposing an immediate 14 percent import tariff on chips from countries that have failed to open their markets fully to U.S. chips. Micron's dumping suit against its Japanese competitors in the mid-'80s led to the first U.S.-Japan semiconductor trade pact.

MAR 12. Silicon Graphics Inc., Mountain View, Calif., said it would buy **MIPS Computer Systems Inc.**, Sunnyvale, Calif., a leader in reduced-instruction-set computing (RISC) ICs. Silicon Graphics, the leading maker of workstations with 3-D graphics, said the combined company—expected to total nearly US $1 billion in annual revenues—will aim to establish MIPS's RISC technology as an alternative to Intel Corp.'s microprocessors.

MAR 12. The **Federal Communications Commission**, Washington, D.C., said it would more than double the number of radio stations that a single company may own—from 12 to 30—and would also allow a single owner as many as three AM and three FM stations in a single city. The ruling drew criticism that the changes will force many mom-and-pop broadcasters out of business and lessen the diversity of U.S. programming.

MAR 13. Philips NV, Eindhoven, the Netherlands, said it would form a joint venture with **Motorola Inc.**, Schaumburg, Ill., aimed at supporting the manufacture of chips for Philips's interactive multimedia consumer electronics unit, called compact-disc interactive (CDI). The price of CDI is expected to fall sharply over the next few years.

MAR 16. The **Federal Aviation Administration**, Washington, D.C., said it awarded **MCI Communications Corp.**, McLean, Va., a 10-year $558 million contract to provide long-distance service in a new network linking the nation's air traffic control system. The network will be designed to prevent the kind of outage that occurred last September when equipment failure in New York City jammed AT&T Co.'s long-distance network.

MAR 17. Researchers at **Pennsylvania State University** in University Park said they had invented a metal-carbon compound likely to have magnetic and electrical properties of use for new electronic materials. The molecule contains eight atoms of titanium and 12 atoms of carbon, which seem to form a hollow, roughly spherical molecule with 12 pentagon-shaped faces—a structure apparently similar to that of soccerball-shaped carbon ''buckeyballs.''

MAR 19. Toshiba Corp., Tokyo, said it had developed a new X-ray machine that can produce images in about 10 seconds with less than one-tenth the normal X-ray dose and no film. The company said the equipment is the first to print X-ray images on plain paper in a quasi-photocopy process.

MAR 19. Researchers at the **University of Pennsylvania**, Philadelphia, and **Ohio State University**, Columbus, reported that they have increased by a factor of 10 the amount of electricity a conducting plastic will carry. Small crystalline centers formed within a conducting plastic called polyaniline cause the molecules to align so that electrons can easily hop between them. Among potential applications is shielding equipment from electromagnetic interference.

MAR 24. Microsoft Corp., Redmond, Wash., said it would buy **Fox Software Inc.**, Perrysburg, Ohio, a provider of database software, in a stock swap valued at $173 million. The purchase includes Fox's Foxpro package and puts Microsoft into the one big area of the PC software business in which it had not yet participated.

MAR 25. The Swiss-Swedish **Asea Brown Boveri (ABB)**, Zurich, and Japan's **Marubeni Corp.**, Osaka, said they had signed a pact with **Perusahaan Umum Listrik Negara (PLN)**, the Indonesian state electricity company, to build the $684 million Tanjung Priok power station. Construction of the 1180-MW combined-cycle (gas and steam) plant is to begin this spring.

MAR 25. Space program officials in Moscow said that **Russian astronaut Sergei Krikalev** had returned to earth after 313 days on the Mir space station. He stayed five months longer than intended because of the breakup of the Soviet Union and lack of money in Moscow.

MAR 26. Motorola Inc., Schaumburg, Ill., said it will let cellular-phone operators use its closely guarded technology for tying computers into mobile-data networks. Until now, Motorola granted access to its Ardis computer-data network only to its own subscribers. The company will also let others use its packet-data system technologies so that carriers may offer computer-data as well as voice services.

MAR 27. The **Bush administration** announced it had cleared the way for the U.S. purchase of several key technologies from the former Soviet Union. Included are a Russian Topaz 2 nuclear reactor for space power, four Hall thrusters for moving objects in space, and plutonium-238 to build nuclear batteries for a new generation of deep-space probes.

MAR 30. Texas Instruments Inc., Dallas, said it had agreed to produce a new microprocessor chip designed by **Cyrix Corp.**, Richardson, Texas, and market it under the TI name. Cyrix said the CX4868SLC, a hybrid of Intel Corp.'s 386 SX and 486, performs nearly as well as Intel's 486SX but sells for much less— $119 vs. $200–$300. Cyrix's chips are also made by French-Italian **SGS-Thomson Microelectronics NV,** which has a license to use Intel patents, as does TI.

APR 2. AT&T Co. announced a three-chip coder-decoder that will allow people in different cities to see and talk to each other over their PCs. The company said the $400 AVP-100 could break a cost barrier excluding videoconferencing from the lucrative mass market.

APR 2. The **space shuttle Atlantis** returned to earth after circling the globe 142 times in nine days while its crew studied the chemistry and physics of the earth's upper atmosphere, a program known as Mission to Planet Earth.

Preview:

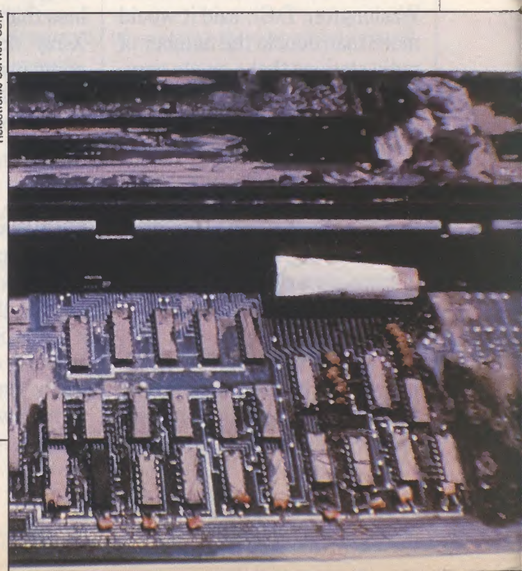
MAY 7. The space shuttle **Endeavor,** NASA's $2 billion replacement for the **Challenger,** is to be launched from the Kennedy Space Center, Cape Canaveral, Fla. Its mission will be to attach a booster motor to a three-year-old Intelsat telephone satellite—now in a decaying orbit—and relaunch it into a higher orbit.

COORDINATOR: Sally Cahur

MAY 1992 Volume 29 Number 5

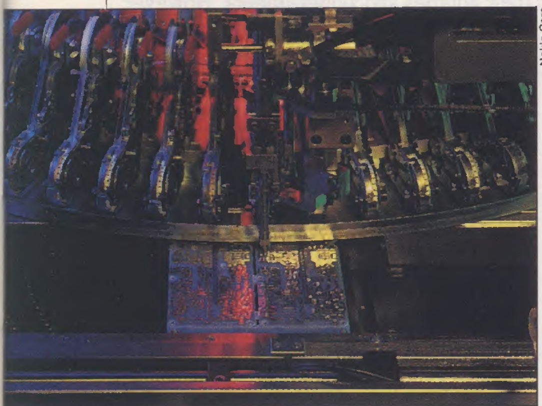
IEEE SPECTRUM

Relectronic Service Corp.



FOR THE RECORD

PROFILE



Nokia Corp.

SPECTRAL LINES

Cover: The changes now under way in IC supply voltages are illustrated in this conceptual cover by designer Gus Sauter. The drawing shows 3.3 V in the ascendant as 5 V fades into the background. But what's that in the foreground? See p. 22.

IEEE SPECTRUM (ISSN 0018-9235) is published monthly by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. © 1992 by The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th St., New York, N.Y. 10017, U.S.A. Cable address: ITRIPLEE. Telex 236-411. Telecopier: 212-705-7453.
ANNUAL SUBSCRIPTIONS. IEEE members: $10.00 included in dues. Nonmembers: $29.95. Libraries/institutions: $139.
SINGLE COPIES. Members: $8 first copy, $16 per additional copy. Nonmembers: $16.
MICROFICHE SUBSCRIPTIONS. Members: $16. Nonmembers and libraries: $139.
POSTMASTER: Please send address changes to *IEEE Spectrum*, c/o Coding Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855. Second Class postage paid at New York, N.Y., and additional mailing offices. Canadian GST #125634188.
Printed at 8649 Hacks Cross Rd., Olive Branch, Miss. 38654.

IEEE Spectrum is a member of the Audit Bureau of Circulations, the Magazine Publishers of America, and the Society of National Association Publications.

Staff

EDITOR AND PUBLISHER: Donald Christiansen

EXECUTIVE EDITOR: Edward A. Torrero

MANAGING EDITOR: Alfred Rosenblatt

SENIOR TECHNICAL EDITOR: Gadi Kaplan

SENIOR EDITORS: Trudy E. Bell, Richard Comerford, Tekla S. Perry, Michael J. Riezenman, George F. Watson

SENIOR ASSOCIATE EDITORS: John A. Adam, Glenn Zorpette

HEADQUARTERS: New York City 212-705-7555
BUREAUS: WASHINGTON, D.C., John A. Adam, 202-544-3790; *SAN FRANCISCO,* Tekla S. Perry, 415-282-3608

CORRESPONDENTS: Fred Guterl, Roger Milne (London); Bradford Smith (Paris); John Blau (Düsseldorf); Robert Ingersoll (Bonn); John Mason (Barcelona); Stuart M. Dambrot, Roger Schreffler (Tokyo); Kim Nak-Hieon (Seoul); Chris Brown (Taipei); Peter Gwynne (Hong Kong); Tony Healy (Sydney, Australia); Christopher Trump (Toronto); Axel de Tristan (Rio de Janeiro); Kevin L. Self (Houston)

CHIEF COPY EDITOR: Margaret Eastman
COPY EDITOR: Sally Cahur
EDITORIAL RESEARCHER: Alan Gardner

CONTRIBUTING EDITORS: Karl Esch, Ronald K. Jurgen, Michael F. Wolff

EDITORIAL INTERNS: George Likourezos, Dana Norvila

EDITORIAL SUPPORT SERVICES: Rita Holland (Manager)
EDITORIAL ASSISTANTS: Ramona Foster, Desiree Noel

DESIGN CONSULTANT: Gus Sauter

OPERATIONS DIRECTOR: Fran Zappulla
BUSINESS MANAGER: Robert T. Ross

EDITORIAL PRODUCTION:
Carol L. White (Director)
Marcia Meyers (Manager)
Peter Ruffett (Typographer)
Morris Khan (Technical Graphic Artist)

ASSOCIATE PUBLISHER: William R. Saunders
ADMINISTRATIVE ASSISTANT: Carmen Cruz
MAIL LIST SALES: Shelly Newman (Manager), Lizette Graciani
ADVERTISING PRODUCTION: Theresa Fitzpatrick (Manager), Francesca Silvestri

MARKETING DIRECTOR: Arthur C. Nigro
PROMOTION MANAGER: Robert D. Moran
RESEARCH MANAGER: Hendrik Prins
MARKETING SERVICES: Eric Sonntag (Administrator)

ADMINISTRATIVE ASSISTANT TO THE EDITOR AND PUBLISHER: Nancy T. Hantman

Forum

Beyond reality

I really enjoyed Robert W. Lucky's "What's real anymore?" [November, p. 6]. I was a defector from the family line of chemists and chose EE in the days when hardware was hardware.

One time, a few years back, I was troubleshooting an I&Q correlator for some radar system. Yes, I knew about in-phase and quadrature sampling, analog-to-digital conversion, and phasor diagrams, but I still caught myself staring into the circuit boards and wondering "where those little spinning arrows" went...

John D. Fogarty
Columbia, Md.

Kilowatthours vs. joules

On p. 18 [third column, second paragraph] of the March 1991 issue, the author says "The package will produce 100 kW continuously, for seven years or for a total of over 22 GJ." The 22 is correct, but the GJ (gigajoules) should be TJ (terajoules), a difference of 1000. Mega, giga, tera—it would have been better to use kilowatthours (kWh).

James H. Skog
Seattle, Wash.

Reader Skog is right. A 100-kW power source running continuously for seven years will produce 22 terajoules (22×10^{12} joules). The metric practice adopted by the IEEE recognizes that the unit "kilowatthour" might be retained for a time because of its wide use; however, the joule is the unit accepted in the international system of units, or SI. —*Ed.*

EMF on computer

In the November 1991 issue, "Simulating EM fields" by Daniel G. Swanson Jr. drew my attention because of my 25 years of experience in this domain and my links with the IEEE Magnetic Society.

I was very disappointed by this paper for two reasons: first, the analysis omitted the capabilities of pre- and postprocessors and the low-frequency range; the second one is the xenophobic aspect of the report on representative software. As a matter of fact, many specifically U.S. packages, generally unknown by the scientific community, are mentioned, while some famous leading software [packages] like Tosca (distributed by Vector Fields) or FLUX3D (distributed by Cedrat and Magsoft) or Mega (Bath University) are not.

J. Sabonnadière
Saint Martin d'Hères, France

The author responds:
My article was not intended to be an all-inclusive review of electromagnetic field analysis, and I am sorry if readers received that impression. In the limited space allowed, I chose to focus on RF/microwave and high-speed digital applications. My purpose was to make working engineers aware of new software tools that could help them compete in today's global market. In the body of the article, I did not discuss low-frequency electrostatics and magnetostatics, accelerator physics, antennas, radar cross section, or many other areas where numerical codes are of interest.

I am afraid "xenophobic" is a rather strong term when applied to a vendor list that included two Canadian and one German firm. I am aware of the Tosca code, and I apologize to Vector Fields for not including them. I could have also included Mafia, Argus, SOS, Poisson, Superfish, NEC, ESP . . . a complete list would fill several pages.

Puzzle picture

On p. 37 of the December issue ["IEEE's Posix: making progress" by D. Richard Kuhn], the screen appears to show Fortran code, but the caption says it was written in ANSI C. What was the author's intent?

Darrell Call
Los Alamos, N.M.

The author responds:
The picture shows the output of a tool that analyzes Fortran program source code using a technique called "slicing," which is explained in the photo caption. As noted in the caption, the data flow and slicing code (that is, the tool itself) was written in ANSI C. I apologize for any misunderstanding.

More light on photonics

As vice president for sales and marketing of Astarte Fiber Networks Inc., I would like to point out an omission in H. Scott Hinton's chart on p. 45 of the February issue ["Switching to photonics"], as well as in his implications about other sources of photonic switches.

Astarte Fiber Networks has photonic switches installed at customer locations in the United States, Europe, and Australia. These photonic matrix switches offer: photonic connectivity without electronic conversion, compatibility with network standards, and the ability to accommodate transmission bandwidths in excess of 10 GHz. Additionally, Astarte offers switching matrices up to 64 input fibers to 64 output fibers, which is over four times the capacity of any of the switches outlined in the article.

Astarte is currently shipping and installing systems to connect some of the more advanced optical-fiber networks around the world. Applications include FDDI interconnection, flight simulators, computer-to-computer networking, and telephony.

Ken Garrett
Boulder, Colo.

Fair values

The Potavin and Harvey letters [April, p. 6] discussed a purported lack of balance in the profiles of eight innovators. I have long hoped that our society would reach a point where individuals would be judged solely on their abilities and achievements. However, replacing outdated values that inhibited or devalued the accomplishments of certain groups (such as minorities or women) with a new system that inhibits or devalues the accomplishments of other groups (such as white or Asian males) is merely the replacement of one despot with another.

Herbert E. Kook Jr.
Clinton, Miss.

Credit where it's due

We inadvertently omitted to name the photographer responsible for the picture of the assemblage on the cover of the April issue. He is Chuck Kintzing. —*Ed.*

Correction

On p. 20 of the February issue, the caption erroneously states that the European Space Agency's proposed European Remote Sensing Satellite ERS-1 is shown over Arctic terrain. In fact, the satellite is superimposed on a photograph of a massive iceberg near the Ross Ice Shelf in Antarctica. —*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contacts: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453.

Calendar

Meetings, Conferences and Conventions

MAY

Electro '92 (Region 1 et al.); May 12–14; Hynes Convention Center, Boston; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-215-3976; 800-877-2668.

International Symposium on Semiconductor Manufacturing Technology—ISSMT '92 (ED); May 14–15; The Hotel New Otani, Tokyo, Japan; Tadahiro Ohmi, Department of Electronics, Tohoku University, ASA-Aoba, Aramaki, Sendai 980, Japan; fax, (81+022) 224 2549.

Symposium on Worldwide Advances in Communication Networks (COM); May 14–15; George Mason University, Fairfax, Va.; Telecommunications Laboratory, ECE Department, George Mason University, Fairfax, Va. 22030-4444; 703-993-1566; fax, 703-993-1521.

42nd Electronic Components and Technology Conference (CHMT); May 18–20; Sheraton Harbor Island Hotel, San Diego, Calif.; Peter J. Walsh, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, D.C. 20006-1903; 202-457-4932.

National Aerospace and Electronics Conference (AES, Dayton Section); May 18–22; Dayton Convention Center, Dayton, Ohio; Sue Brown, ASD/ENES, Wright-Patterson Air Force Base, Ohio 45433-6503; 513-255-6281.

National Telesystems Conference (AES, NCAC); May 19–20; George Washington University, Ashburn, Va.; Elena Jurgela, George Washington University Dept. of Engineering, 20101 Academic Way, Suite 227, Ashburn, Va. 22011; 703-729-8250.

Fourth International Symposium on Power Semiconductor Devices and ICs (IEE Japan, ED); May 19–21; Waseda University, International Conference Center, Shinijuki-ku, Tokyo; Hiromichi Ohashi, Electron Devices Laboratory, Toshiba R&D Center, 1, Komukai Toshiba-cho, Saiwai-ku, Kawasaki 210, Japan; (81+44) 549 2063.

36th International Symposium on Electron, Ion, and Photon Beams (ED); May 26–29; Peabody Hotel, Orlando, Fla.; Randy Kubena, Hughes Research Laboratories, 3011 Malibu Canyon Rd., Malibu, Calif. 90265; 310-317-5423.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7305.

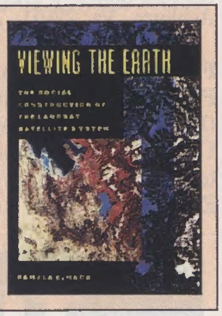
For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Books

Seeing earth from a different perspective

Joanne Irene Gabrynowicz

Viewing the Earth: The Social Construction of the Landsat System. *Mack, Pamela E., MIT Press, Cambridge, Mass., 1991, 270 pp., $27.50*



Winston Churchill, a statesman known for his far-reaching vision, believed that "the farther backward you can look, the farther forward you are likely to see." This is as true of technological change as it is of momentous political decisions. In fact, the former is increasingly becoming the cause of the latter.

In this book, Pamela E. Mack takes the reader back to the 1950s, which, historically speaking, was to satellite development what the Renaissance was to today's nation-state system. That vantage point helps the author clarify the reasons for the choices made in the development of the Landsat system. Examining technological development from the perspective of a historian is something the technological, scientific, and political communities ought to do often, and this book is a good place to start.

Mack's productive and provocative focus is the role of interest groups in shaping technological change. It demonstrates the importance of recognizing the human side of technology, and also begins to grapple with a complex situation and expand the inquiry to include culture and politics as well as science and technology.

First launched in 1972, the satellites in the Landsat system were the first source of nearly standardized, continuous land remote-sensing data. In helping to develop Landsat, each of the public sector organizations involved—the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey, the departments of Defense, Commerce, Interior, Agriculture, and the Office of Management and Budget—has a fully developed distinct culture based on its own specific mission and degree of political and financial support. The author describes the viewpoints of each of these cultures, and shows how making technology programs viable takes an intricate blend of science, strategies, policies, perceptions, engineering, experimentation, and quite often, luck.

What I appreciated most about the book are the conceptual tools used to describe historical events. Descriptions of relationships, community identities, dynamics, subjective perspectives, and story-telling all raise the book's subject matter above the often mind-numbing accounts of technology projects that rely on indecipherable acronyms, "specs," codes, numbers, and technical jargon.

One of the most effective conceptual tools used by Mack is contextual analysis. Often, analyses of technological programs focus on changes made at various stages of research, design, or development, and the subsequent chain of cause-and-effect events is considered to have come from those changes. The impression is given that a technology's life span is a linear event traceable from point A to point B, and that finding where a change in direction occurred merely requires plotting a series of points.

In fact, there are myriad nonlinear and coexisting political, economic, and social forces at play in any technology's development. Some, at times, are more dominant than others, and often they exchange positions of influence. By describing the "interaction of technology and context," Mack allows the reader to observe more clearly the dynamic relationships among the various individuals and bureaucracies that attempted to carry out their own particular interests while helping to develop Landsat.

Mack also uses three types of voices in her account, shattering the illusion that official technological opinions are monolithic pronouncements. Agency leaders are distinguished from departments and centers, and agencies are distinguished from the executive office of the President.

In addition to its novel approach, this book offers some substantive lessons. Foremost among them is that a coherent U.S. space policy is, in fact, nonexistent. Policy is formulated by whichever interest group or groups happen to prevail in the complex competition to control a technology's development. As it affects Mack's subject—Landsat—this deplorable situation is particularly significant now.

Landsat satellites are essential to providing a comparative database for the soon-to-be-launched Earth-Observing System and other environmental monitoring satellites, which will provide information for policy decisions with consequences that will last for decades. Currently, such precedents as the cost of Landsat data and its availability to diverse users are at the heart of debates in Congress, the National Space Council, NASA, the Department of Defense, and the scientific community.

(Continued on p. 12)

FREE TO IEEE MEMBERS!

This Easy-to-use Disk* Helps You *Plan Your Financial Future* in Less Than an Hour!

*For IBM PC's and compatible systems

NEW

Improved 1992 Edition

- FASTER
- EXPANDED DATA
- PROFESSIONAL ADVICE

Here's how to get your copy of the FREE *LifeCycle Review* Disk.

Complete the following information and return this card *today!*

Please print or type.

SIZE OF DISK PREFERRED ☐ 5¼" ☐ 3½"

MR ☐ MRS ☐ MS ☐ NAME

ADDRESS

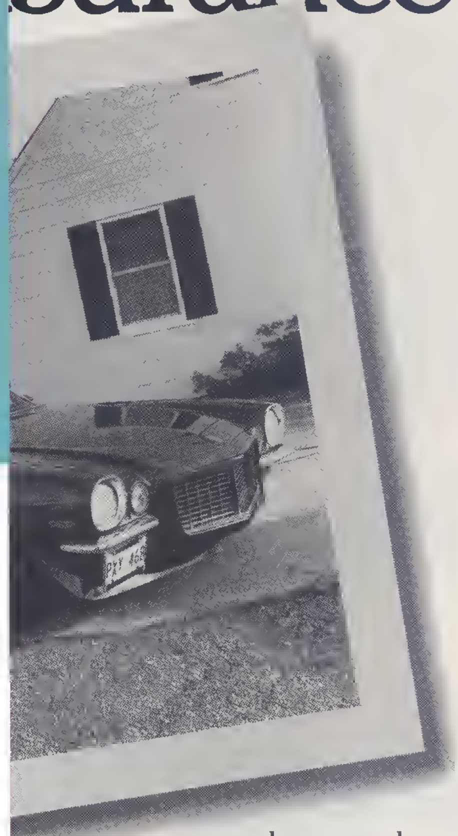
CITY STATE ZIP

DAY TELEPHONE ( ) DATE OF BIRTH / / MO. DAY YR.

IEEE MEMBER NUMBER

54191-3/92

e Car You ng The Last ought About surance?



association is designed to grow with you — it even moves with you when you change jobs.

We're Affordable.

What good would all these benefits be if no one could afford them? That's why we offer members the additional benefit of reasonable rates, negotiated using our group purchasing power. Call 1 800 424-9883 (in Washington, DC, (202) 457-6820) between 8:30 a.m. and 5:30 p.m. Eastern Time for more information about these insurance plans offered through IEEE:

Term Life • Disability Income Protection • Comprehensive HealthCare • Excess Major Medical • In-Hospital • High-Limit Accident • Long Term Care • Medicare Supplement • Cancer Expense

IEEE Insurance

Designed for the way you live today. And tomorrow.

Seeing earth fro
a different persp
Joanne Irene Gabryn

Viewing the Earth: The Social Construction of the Landsat System.
Mack, Pamela E., MIT Press, Cambridge, Mass., 1991, 270 pp., $27.50

Winston Churchill,
his far-reaching vi
farther backward y
forward you are lik
true of technologi
momentous politic
former is increasin
of the latter.

In this book, Par
reader back to the
ly speaking, was t
what the Renaissan
state system. That
author clarify the
made in the develop
tem. Examining tec
from the perspectiv
thing the technolog
litical communities
this book is a good

Mack's productiv
is the role of interes
nological change. It
tance of recognizing
nology, and also b
complex situation
to include culture
science and techno

First launched in
Landsat system w
nearly standardiz
remote-sensing dat
Landsat, each of the
tions involved—the
Space Administratio
logical Survey, the
Commerce, Interio
Office of Managem
fully developed dist
own specific missio
and financial suppor
the viewpoints of ea
shows how making t
ble takes an intricate
gies, policies, perce
perimentation, and

What I appreciate

Books

(Continued from p. 8)

Mack also covers a related lesson: that technology development is not necessarily driven by how a technology will be used; different drivers result in different degrees of effectiveness. The spectrum of possibilities runs from "a new technology that simply responds to recognized needs [and] is likely only to be a small advance. . . [to] . . . a new technology developed because it is technically exciting rather than because it meets a need [and] is likely to be an expensive failure."

This analysis underscores the necessity for policymakers to raise questions of purpose—asking, for example, why a technology should be pursued and what good it is intended to achieve. Members of the National Space Council, who are responsible for articulating a national remote-sensing policy, would do well to read this book.

Another of the book's lessons is that subjectivity, communication, and language directly affect the success of a technology. This is so, according to the author, because different groups involved in technological change have "radically different" perspectives on a technology. Thus, a technology is "socially constructed" rather than created on the basis of its ultimate use.

Overall, this book will prove valuable to anyone interested in learning more about the process of technological development in the United States in general and the development of the Landsat system in particular.

Joanne Irene Gabrynowicz is an attorney and associate professor in the space studies department at the University of North Dakota in Grand Forks. She teaches domestic and international space law and policy, including a course titled "Remote Sensing Law and Policy." Her commentaries on remote sensing law and policy have appeared in Space News *and other publications.*

Books in brief

The McGraw-Hill Encyclopedia of Science and Technology *(7th edition). Parker, Sybil P., Editor-in-Chief, McGraw-Hill, New York, 1992, 13 450 pp., $1700 (until June 30; $1900 thereafter).*

Is there any such thing as an unbreakable cipher? How many atoms of element 109 have been produced? What is the largest oasis in the Sahara desert?

If these kinds of questions have ever given you pause, this encyclopedia may be just what you need. First published in 1960, it has become the largest and most widely used reference of its kind. Although most of its entries are written by experts (including 21 Nobel laureates), all are intended to be understandable to the student or layperson, as well as useful to the specialist.

Computer science, electronic circuits, solid-state physics, radio, telecommunications, control systems, and electromagnetic radiation and optics are among the encyclopedia's 81 major subject areas. Entries new to the seventh edition are in such areas as bioelectronics, buffers, chaos, fuzzy logic, lidar, magnetic levitation, neural networks, and power integrated circuits. Of the 7500 articles in the latest edition, 230 are new, 700 were rewritten, and 800 were extensively revised.

There are also nearly 2000 additional illustrations, over and above the 11 000 that have appeared in previous editions. Among the new full-color photographs are striking views of Neptune as seen by Voyager and Venus as seen by Magellan. All told, there are 15 new pages of color photography among the 81 total pages of color photos.

For those still puzzling over the questions posed above, the answers, according to the seventh edition, are: yes, one, and Talfilalet, Morocco (518 km²). *Contact: McGraw-Hill Inc., Attn.: Joanne Widmer, Blue Ridge Summit, Pa. 17294-0850; 800-262-4729.*

COORDINATOR: Glenn Zorpette

Recent books

Desktop Publishing by Design. *Shushan, Ronnie, et al.*, Microsoft Press, Redmond, Wash., 1991, 345 pp., $24.95.

Digital Electronics. *Bartelt, Terry L.M.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 468 pp., $44.

Microcomputers and Microprocessors: the 8080, 8085, and Z-80 programming, interfacing, and troubleshooting, 2nd edition. *Uffenbeck, John*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 690 pp., $52.

Adaptive Data Compression. *Williams, Ross N.*, Kluwer Academic, Norwell, Mass., 1991, 382 pp., $75.

Digital Systems: principles and applications, 5th edition. *Tocci, Ronald J.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 765 pp., $52.

Theory of Dielectric Optical Waveguides, 2nd edition. *Marcuse, Dietrich*, Academic Press, San Diego, Calif., 1991, 380 pp., $59.95.

Introduction to Magnetism and Magnetic Materials. *Jiles, David*, Chapman & Hall, New York, 1991, 440 pp., $115.

Recent Network Theorems. *Stockman, Harry E.*, Sercolab, East Dennis, Mass., 1991, 156 pp., $7.

Microprogramming and Computer Architecture. *Segeem, Bruce*, and *Field, John*, John Wiley & Sons, Somerset, N.J., 1991, 362 pp., $56.95.

Semiconductor Devices for Electronic Tuners. *Watanabe, Seiichi*, Howard Academic, New York, 1991, 142 pp., $70.

Coherence, Amplification, and Quantum Effects in Semiconductor Lasers. Ed. *Yamamoto, Yoshihisa*, John Wiley & Sons, Somerset, N.J., 1991, 646 pp., $74.95.

Running Microsoft Excel: the Cobb Group. *Cobb, Douglas, et al.*, Microsoft Press, La Vergne, Tenn., 1991, 766 pp., $27.95.

Prevention of Pressure Sores: engineering and clinical aspects. Ed. *Webster, J.G.*, IOP Publishing, New York, 1991, 250 pp., $60.

Build Your Own PostScript Laser Printer: and save a bundle. *LaBadie, Horace W. Jr.*, McGraw-Hill, New York, 1991, 149 pp., $16.95.

Sir Charles Frank, OBE, FRS: an eightieth birthday tribute. Eds. *Chambers, R.G., et al.*, IOP Publishing, New York, 1991, 448 pp., $55.

Semiconductor Devices. *Cooke, M.J.*, Prentice-Hall, New York, 1991, 353 pp., $35.95.

Electronic Signals and Systems. *Prentiss, Stan*, McGraw-Hill, New York, 1991, 316 pp., $19.95.

The Wheeling and Transmission Manual. Eds. *Weiss, Larry*, and *Spiewak, Scott*, Fairmont Press, Lilburn, Ga., 1991, 240 pp., $95.

Genetic Algorithms and Robotics: a heuristic strategy for optimization. *Davidor, Yuval*, World Scientific, Teaneck, N.J., 1991, 164 pp., $28.

Energy Dissipation in Superconducting Materials. *Kovachev, V.*, Oxford University Press, New York, 1991, 229 pp., $90.

Dynamic Analysis of Robot Manipulators: A Cartesian Tensor Approach. *Balafoutis, Constantinos A.*, and *Patel, Rajnikant V.*, Kluwer Academic, Dordrecht, the Netherlands, 1991, 292 pp., $69.95.

Building Turbo Pascal Libraries. *Soybel, Jeremy G.*, Windcrest/McGraw-Hill, Blue Ridge

Recent books

Summit, Pa., 1991, 443 pp., $24.95.

Testing and Diagnosis of Analog Circuits and Systems. Ed. *Liu, Ruey-wen*, Van Nostrand Reinhold, New York, 1991, 284 pp., $54.95.

Power Systems Handbook: design, operation and maintenance. *Seevers, O.C.*, Fairmont Press, Lilburn, Ga., 1991, 367 pp., $48.

Electro-Optical System Design: for information processing. Eds. *Fischer, Robert E.*, and *Smith, Warren J.*, McGraw-Hill, New York, 1991, 343 pp., $49.95.

CICS: A Programmer's Reference. *Donofrio, Phyllis*, McGraw-Hill, New York, 1991, 254 pp., $44.95.

Routing and Dimensioning in Circuit-Switched Networks. *Girard, Andre*, Addison-Wesley, Reading, Mass., 1991, 556 pp., $60.25.

OS to OS/2: conversion, migration, and application design. *Ranade, Jay*, and *Bobak, Angelo*, McGraw-Hill, New York, 1991, 699 pp., $49.95.

Genome: The Story of Our Astonishing Attempts to Map All the Genes in the Human Body. *Biship, Jerry E.*, and *Waldholz, Michael*, Simon & Schuster, New York, 1991, 352 pp., $10.95.

Digital Signal Processing: theory, applications and hardware. *Haddad, Richard A.*, and *Parsons, Thomas W.*, W.H. Freeman, New York, 1991, 636 pp., $54.95.

Microwave Imaging Techniques. *Steinberg, Bernard D.*, and *Subbaram, Harish M.*, John Wiley & Sons, Somerset, N.J., 1991, 361 pp., $64.95.

Writing VAX/VMS Applications Using Pascal. *De Klerk, Theo*, Digital Press, Bedford, Mass., 1991, 748 pp., $39.95.

Innovative Applications of Artificial Intelligence 2. Eds. *Rappaport, Alain*, and *Smith, Reid*, MIT Press, Cambridge, Mass., 1991, 310 pp., $25.

The V Series Recommendations: Protocols for Data Communications Over the Telephone Network. *Black, Uyless*, McGraw-Hill, New York, 1991, 186 pp., $34.95.

Fundamentals of Manipulator Calibration. *Mooring, Benjamin W., et al.*, John Wiley & Sons, Somerset, N.J., 1991, 329 pp., $69.95.

Mechanisms and Mechanical Devices Sourcebook. *Chironis, Nicholas P.*, McGraw-Hill, New York, 1991, 447 pp., $55.

Digital Image Processing. *Pratt, William K.*, John Wiley & Sons, Somerset, N.J., 1991, 698 pp., $69.95.

FoxPro: The Master Reference. *Stark, Robin*, and *Satonin, Shelley*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 390 pp., $24.95.

Understanding Hypertext Concepts and Applications. *Seyer, Philip*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 280 pp., $29.95 (hardcover), $19.95 (paperback).

Vector Lyapunov Functions and Stability Analysis of Nonlinear Systems. *Lakshmikantham, V.*, *Matrosov, V.M.*, and *Sivasundaram, S.*, Kluwer Academic, Dordrecht, the Netherlands, 1991, 172 pp., $79.

Norton Utilities 5.0: An Illustrated Tutorial. *Evans, Richard*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 343 pp., $16.95.

A Model for Distributed Campus Computing. *Champine, George A.*, Digital Press, Bed-

Recent books

ford, Mass., 1991, 300 pp., $28.95.

Designing With Speech Processing Chips. *Jimenez, Ricardo,* Academic Press, San Diego, Calif., 1991, 323 pp., $59.95.

Lee Adams' Visualization Graphics in C. *Adams, Lee,* Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 512 pp., $26.95.

Improving Engineering Design. *National Research Council,* National Academy Press, Washington, D.C., 1991, 107 pp., $19.

Quantized Vortices in Helium II. *Donnelly, R.J.,* Cambridge University Press, New York, 1991, 346 pp., $95.

Solder Joint Reliability: Theory and Applications. Ed. *Lau, John H.,* Van Nostrand Reinhold, New York, 1991, 631 pp., $74.95.

The Art of Computer Systems Performance Analysis. *Jain, Raj,* John Wiley & Sons, New York, 1991, 720 pp., $52.95.

Neural Networks and Speech Processing. *Morgan, David P.,* and *Scofield, Christopher L.,* Kluwer Academic, Dordrecht, the Netherlands, 1991, 391 pp., $69.96.

Computer Security Handbook, 2nd edition. *Baker, Richard H.,* Tab Books/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 416 pp., $24.95.

Practical Knowledge Engineering. *Kelly, Richard V. Jr.,* Digital Press, Bedford, Mass., 1991, 230 pp., $28.95.

Unix Quick! *Feibus, Andrew,* Professional Press, Horsham, Pa., 1991, 249 pp., $30.

80386 Protected Mode Programming in C. *Dorfman, Len,* Tab Books/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 384 pp., $24.95.

Digital Magnetic Recording, 2nd edition. *Hoagland, Albert S.,* and *Monson, James E.,* John Wiley & Sons, Somerset, N.J., 1991, 230 pp., $49.95.

Designing Intelligence: A Framework for Smart Systems. *Kim, Steven H.,* Oxford University Press, New York, 1991, 273 pp., $39.95.

SVD and Signal Processing II. Ed. *Vaccaro, R.,* Elsevier Science, Amsterdam, the Netherlands, 1991, 512 pp., $85.

The CAD Design Studio. *Jacobs, Stephen Paul,* McGraw-Hill, New York, 1991, 120 pp., $29.95.

Optimal Control: An Introduction to the Theory with Applications. *Hocking, Leslie M.,* Oxford University Press, New York, 1991, 254 pp., $80.

Adaptive and Digital Signal Processing. *Lindquist, Claude S.,* Stewart & Sons, Miami, Fla., 1991, 847 pp., $44.95.

Implementation of Non-Strict Functional Programming Languages. *Traub, Kenneth R.,* MIT Press, Cambridge, Mass., 1991, 171 pp., $27.95.

Oracle Distributed Systems. *Webb, Kenneth,* and *Lafreniere, Lori,* Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 329 pp., $24.95.

Singular Electromagnetic Fields and Sources. *Van Bladel, J.,* Oxford University Press, New York, 1991, 237 pp., $75.

The Big Bang That Never Happened. *Lerner, Eric,* Random House, New York, 1991, 466 pp., $21.95.

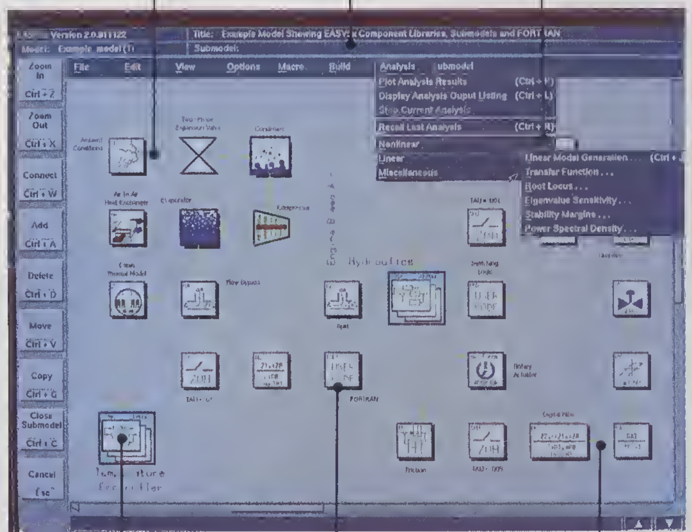
1991 Yearbook Supplement To McGraw-Hill's National Electrical Code Handbook. *McPart-*

(Continued on p. 52G)

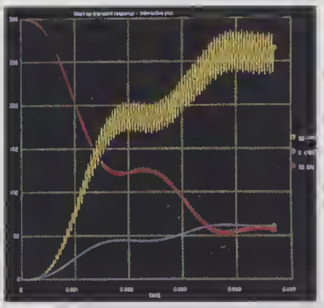
EASY5x.®

It gives you the power to visualize complex problems *the way you want to see them.*

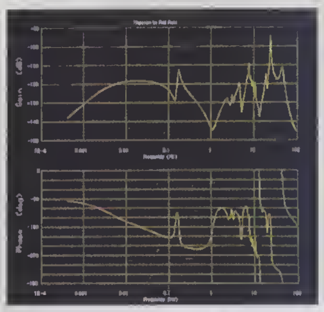
Model documented via user-defined icons. *Motif®-based graphical user interface.* *Wide variety of non-linear and linear analyses.*



Nested "submodels" simplify large models. *User-supplied code integral to block diagram.* *Continuous and multi-rate sampled-data components.*



Non-linear simulation results viewed interactively or off-line.



Frequency-response data displayed in Bode, Nichols, or Nyquist formats.

Almost all engineering analysis software works fairly well on nickle-and-dime problems. But when it comes to really difficult jobs, you run into a lot of limitations.

EASY5x is different.

It gives you the ability to look at big, complex problems. You can use it to model, simulate, and analyze virtually any type or size of dynamic system—even sampled-data control systems.

Easily build your own components.

With EASY5x's open architecture, you can create your own application-specific components. Then store them, reuse them, and share them with other engineers.

Or, you can use any of our 195 modeling components. These standard "building blocks" will help you efficiently model dynamic effects or physical systems. Including tricky problems like friction and hysteresis, or two-phase refrigeration cycles.

Concentrate on the problem, not the software.

EASY5x gives you unparalleled flexibility. Yet it's easy to learn and simple to use.

The X Window®-based graphical interface lets you work on engineering workstations without forcing you to learn special commands.

And when your problem becomes complex enough for speed to be important, EASY5x is an order of magnitude faster than our competitors' software. You can even run your analyses on a supercomputer.

Designed by engineers for engineers.

EASY5x wasn't created in an academic setting. It was developed, tested, and refined at Boeing, one of the world's leading aerospace companies.

Altogether, in fact, more than 2,700 Boeing engineers have used EASY5x. And the software has logged more than a million man-hours designing the airplanes you fly. But that's only the beginning.

Because thousands of other engineers and students worldwide are using EASY5x to model and analyze electrical, mechanical, hydraulic, pneumatic, thermal, and chemical systems. And they're applying their findings to the aerospace and automotive industries. Plus robotics, heavy equipment, nuclear power, and environmental control.

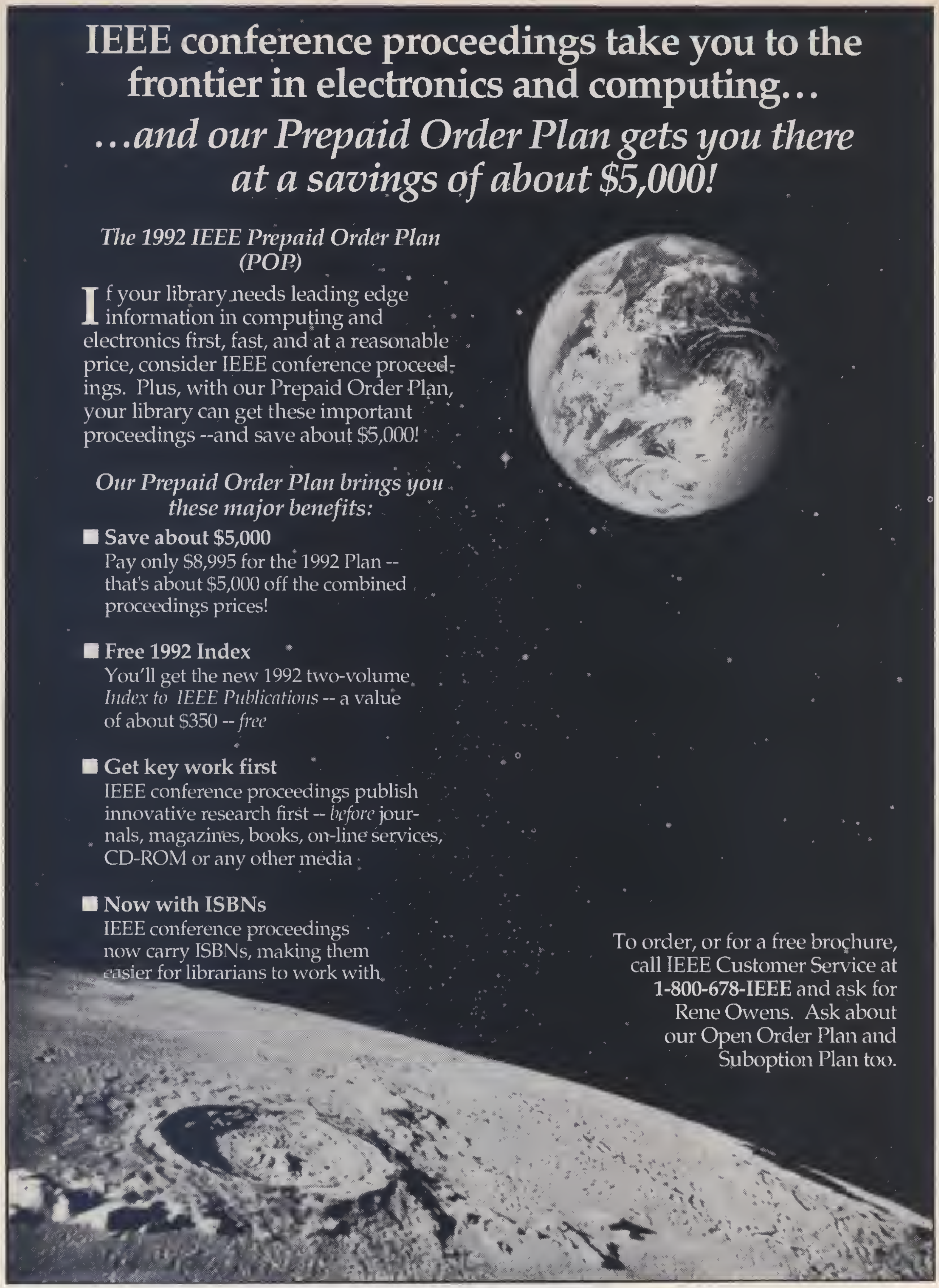
Try EASY5x for free.

All things considered, EASY5x is the best value on the market. And we'd like to prove it to you.

Call us for a free, 30-day trial offer. Phone 1-800-426-1443 or FAX to 206-865-2966. Or write to Boeing, P.O. Box 24346, MS 7L-46, Seattle, WA 98124-0346.

BOEING

Circle No. 34



The Institute of Electrical & Electronics Engineers, Inc. • 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331

Circle No. 8

Calendar

(Continued from p. 7)

International Geoscience and Remote Sensing Symposium (GRS); May 26–29; South Shore Harbour Resort and Conference Center, League City, Texas; Tammy I. Stein, HARC/STAR, 4800 Research Forest Dr., The Woodlands, Texas 77381; 713-363-7922.

46th Annual Symposium on Frequency Control (UFFC); May 27–29; Hershey Lodge and Convention Center, Hershey, Pa.; Raymond L. Filler, U.S. Army ETDL, SLCET-EQ, Fort Monmouth, N.J. 07703-5601; 908-544-2467.

22nd International Symposium on Multiple-Valued Logic (C); May 27–29; Tohoku University, Sendai, Japan; Tatsuo Higuchi, Electronic Engineering Department, Tohoku University, Sendai 980, Japan; (81+022) 222 1800; fax, (81+022) 263 9406.

Workshop on Numerical Modeling of Processes and Devices for Integrated Circuits–Nupad IV (ED); May 31–June 1; Westin Hotel, Seattle, Wash.; Fely Barrera, Stanford University, 205 AEL Building, Stanford, Calif. 94305-4055; 415-723-4138; fax, 415-725-7298.

JUNE

Microwave and Millimeter Wave Monolithic Circuits Symposium (ED); June 1–2; Convention Center, Albuquerque, N.M.; Ho Charles Huang, Anadigics Inc., 35 Technology Dr., Warren, N.J. 07060; 201-668-5000; fax, 908-668-5068.

19th International Conference on Plasma Sciences (NPS); June 1–3; Hyatt Regency Westshore Hotel, Tampa, Fla.; Norman L. Oleson, Department of Electrical Engineering, Eng 118, University of South Florida, Tampa, Fla. 33620; 813-974-2369; fax, 813-974-5250.

International Microwave Symposium—MTT '92 (MTT); June 1–5; Albuquerque Convention Center, Albuquerque, N.M.; Everett Farr, 614 Paseo Del Mar, Albuquerque, N.M. 87123; 505-293-3886.

Symposium on Autonomous Underwater Vehicle Technology (OE); June 2–3; Dulles Airport Marriott Hotel, Washington, D.C.; Gordon Raisbeck, 40 Deering St., Portland, Me. 04101-2212; 207-773-6243.

VLSI Technology Symposium (ED); June 2–4; Westin Hotel, Seattle, Wash.; James Clemens, AT&T Bell Laboratories,

Calendar

600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-2800.

11th Annual International Conference on Consumer Electronics (CE); June 3–5; Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, Conference Coordinator, 67 Raspberry Patch Dr., Rochester, N.Y. 14612-2868; 716-392-3862; fax, 716-392-4397.

Second International Symposium on Atomic Layer Epitaxy (ED); June 3–5; Raleigh Marriott, Raleigh, N.C.; Salah M. Bedair, Department of Electrical Engineering, North Carolina State University, Raleigh, N.C. 27695-7911; 919-515-5704; fax, 919-515-3027.

Workshop on Combinations of Genetic Algorithms and Neural Networks (NN); June 6; Sheraton Inn Harbor, Baltimore, Md.; J. David Schaffer, Philips Laboratories, 345 Scarborough Rd., Briarcliff Manor, N.Y. 10510; 914-945-6168.

International Symposium on Electrical Insulation (DEI); June 7–10; Omni Inner Harbor Hotel, Baltimore, Md.; D. Randy James, Oak Ridge National Laboratory, Box 2008, Building 3147, MS-6070, Oak Ridge, Tenn. 37831-6070; 615-574-0266/6213.

Fifth Human Factors and Power Plants Conference (PE); June 7–11; Sheraton Hotel, Monterey, Calif.; Robert Starkey, B&W Nuclear Service, 3315 Old Forest Rd., Lynchburg, Va. 24501; 804-385-2905.

International Joint Conference on Neural Networks (NN); June 7–11; Baltimore Convention Center, Baltimore, Md.; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222.

Sixth International Conference on Metalorganic Vapor Phase Epitaxy (LEO); June 8–12; Hyatt Cambridge, Cambridge, Mass.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

29th ACM/IEEE Design Automation Conference (C, CAS); June 8–12; Anaheim Convention Center, Anaheim, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Conference on Precision Electromagnetic Measurements (IM); June 9–12; CNIT Paris la Défense, Paris; J. Blouet, Bu-

Calendar

reau National de Métrologie, 22 Rue Monge, F-75005 Paris, France; (33+1) 46 34 4840.

International Semiconductor Manufacturing Science Symposium (CHMT, ED); June 14–17; San Francisco Hilton, San Francisco; Corinne Cargnoni, SEMI, 805 E. Middlefield Rd., Mountain View, Calif. 94043; 415-940-6909; fax, 415-967-5375.

Symposium on Computer-Based Medical Systems (C, EMB); June 14–17; Washington Duke Inn and Golf Club, Durham, N.C.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

International Conference on Communications—ICC/Supercomm '92 (COM, Chicago Section); June 14–18; Chicago Hilton and Towers, Chicago; P. Douglas Lattner, Ameritech Services, 2000 W. Ameritech Center Dr., Hoffmans Estate, Ill. 60196-1025; 708-248-5302.

Second International Conference on Systems Integration (C); June 15–18; Headquarters Plaza Hotel, Morristown, N.J.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Seventh Annual Conference on Computer Assurance (AES, NCAC); June 15–18; National Institute of Standards and Technology (NIST), Gaithersburg, Md.; Rob Ayers, 2551 Riva Road, Annapolis, Md. 21401; 410-266-4741.

Fourth International Conference on Software Engineering and Knowledge Engineering (C); June 17–19; Europa Palace Hotel, Capri, Italy; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Solid-State Sensor and Actuator Workshop (ED); June 21–25; Marriott Hilton Head Resort, Hilton Head Island, S.C.; Steve Senturia, Massachusetts Institute of Technology, Room 39-567, Department of Electrical Engineering, Cambridge, Mass. 02139; 617-253-6869; fax, 617-253-9606.

International Workshop on Hardware Fault-Tolerance in Multiprocessors (C); June 22–23; University of Massachusetts, Amherst; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

50th Annual Device Research Conference (ED); June 22–24; Massachusetts Institute of Technology, Cambridge; Sam Shichijo, Texas Instruments Inc., 12840 Hillcrest, Suite 200, Dallas, Texas 75230; 214-917-7402.

Seventh Annual IEEE Symposium on Logic in Computer Science (C); June 22–25; University of California, Santa Cruz, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

35th International Power Sources Symposium (IA); June 22–25; Hyatt Cherry Hill, Cherry Hill, N.J.; Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3894.

20th Power Modulator Symposium (ED); June 23–25; Myrtle Beach Hilton Hotel, Myrtle Beach, S.C.; Mark Goldfarb, Palisades Institute, 2011 Crystal Dr., Suite 307, Arlington, Va. 22202; 703-769-5588.

Your favorite technical handbooks are now available in soft editions.

A new approach to math.

Introducing the Mathcad 3.1 Software System for Microsoft Windows or UNIX. It revolutionizes math by letting you zip through problems naturally and logically—because it works the way you think. And now it's even more powerful, thanks to new Electronic Handbooks.™

PC MAGAZINE EDITOR'S CHOICE
Mathcad 2.5
3-14-89 issue.
Best of '88
Best of '87

More than a number-cruncher.

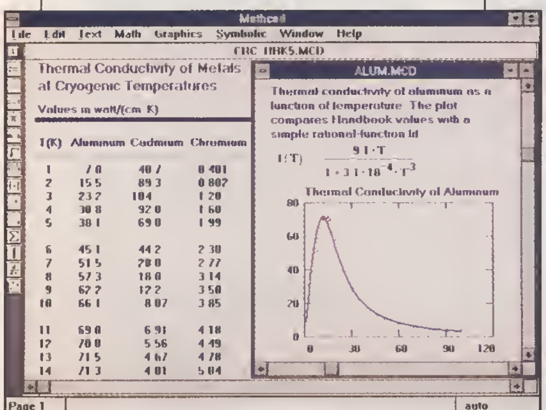
With Mathcad 3.1, you type your work anywhere into the live screen—just like you'd write on a scratchpad—and Mathcad does the calculating. Updates answers when a variable changes. Even graphs in 2-D or 3-D.

Symbolic calculation capabilities let you do integrals, Taylor series, or infinite sum calculations with click-n-drag simplicity.

And when you're done, Mathcad prints out presentation-quality documents complete with equations in real math notation.

Fast electronic access to commonly used methods, formulas and diagrams.

Mathcad's new Electronic Handbooks give you instant access to the formulas, methods,



diagrams and tables you rely on every day. Just open an Electronic Handbook and select your topic. They're interactive, so you can modify formulas for specific calculations. Change parameters, plots and variables, and let Mathcad automatically calculate your answers within the Handbook. Or double-click on a Handbook entry and paste it into your Mathcad document—with the correct units!

Three new optional Mathcad Electronic Handbooks* are now available, each created in conjunction with a leading publisher of technical reference handbooks:

- **Mathcad Treasury of Methods and Formulas** offers you a host of the methods, formulas and diagrams you use every day, along with interactive explanations of every feature and algorithm of Mathcad.
- **Machine Design and Analysis** from Hicks' *Standard Handbook of Engineering Calculations* from McGraw-Hill, contains more than 125 practical calculation procedures including shaft and gear mechanics, time and power to cut, drill, bore, countersink, and a lot more.

PC MAGAZINE THE BEST OF 1991 COVER STORY

- The CRC **Materials Science and Engineering Handbook** contains more than 140 tables of data, bit-mapped illustrations, and Mathcad plots. Includes densities, melting points and crystal structures of elements, properties of ceramics and superconducting materials, and much more.

Also Available:

- **Optional Applications Packs**—adaptable Mathcad templates for Electrical, Mechanical, Civil and Chemical Engineering, Statistics, Advanced Math, and Numerical Methods.
- PC DOS and Macintosh® versions also available.

Free demo disk.

For a FREE Mathcad demo disk, or upgrade information, call 1-800-MATHCAD (or 617-577-1017, Fax 617-577-8829). Or see your software dealer.

UNIX Version now available

*Electronic Handbooks require Mathcad 3.1 and Microsoft Windows 3.0 (or higher) or UNIX.

1-800-MATHCAD

The answer is Mathcad®

MathSoft, Inc. 201 Broadway, Cambridge, MA 02139 USA • Phone: 1-800-628-4223 • 617-577-1017 • Fax: 617-577-8829

Australia: Hearne (03) 866 1766; Belgium: SCIA 013/55 17 75; Denmark: Engberg 42 25 17 77; Finland: Zenex 90-692-7677; France: ISE (1) 46 09 24 00; Germany: Softline (0 78 02) 4036; Italy: Channel 02-90091773; Japan: CRC 03-3665-9741; Netherlands: Klaasing 01620-81600; Sweden: AkademiData (018) 24 00 35; Switzerland: Redacom 032 41 01 11; U.K.: Adept Scientific (0462) 480055. In other locations, contact MathSoft, USA.

Circle No. 9

Technically speaking

Artificial stupidity

An old hardware engineering adage decrees that "computers don't make mistakes, programmers do." Although programmers make similar wisecracks about computer designers, the quip brings up an interesting point: can a computer, or any machine for that matter, make mistakes? How can a computer be blamed if it is doing exactly what it is told to do?

In the *Oxford English Dictionary*, the ultimate resource for English scholars, a mistake is defined as "being in error or estimating wrongly." The word, appropriately enough, comes from the old English word *take*, meaning "to grasp or lay hold of," and *mis*, meaning "to grasp wrongly."

Roget's Thesaurus expands upon that definition to include "an act or thought that unintentionally deviates from what is correct, right or true." This implies that a motive is not necessary to the making of a mistake. Regardless of the cause, if a computer adds 2 + 2 and comes up with pi, it is a mistake.

Similarly, computers can commit errors. The word originates from the Latin word *errare*, which means to wander—a meaning familiar to engineers and scientists who work in plotting data, where error is calculated by the amount data "wanders" from a predetermined point.

The *Oxford English Dictionary* defines error as "a mistake in calculation or judgment done inadvertently through ignorance." Although we often suspect that computers really are sentient, spiteful beings, most of us acknowledge that they are not self-aware. As a result, the term *computer error* is correct, for computers know not what they do.

Further investigation into the etymological underworld unearthed a few more computer traits. Because they are destitute of consciousness, thought, or feeling, computers are stupid. The dictionary also defines stupid as "stubborn or obstinate," a trait we often attribute to our silicon-based friends.

In addition to making mistakes, computers can err in more colorful ways, such as "screw-up," "bungle," and "goof." Experts in the field of artificial intelligence sometimes joke that their goal is to make a computer so smart that it can reason and make mistakes like a human. It appears that computers have already crossed the first hurdle.

Of breadboxes and elephants

Many of us remember a game we played as children in which the goal was to guess the name of some object in a room after being given clues about its size. "Bigger than a breadbox" is one of the most common, followed by "smaller than an elephant." As engineers, we have a reputation for being sticklers for accuracy, and so we present the following statistics on breadboxes and elephants as a public service.

A recent survey of breadboxes conducted at U.S. department stores demonstrated an informal yet consistent standard of 30.48 by 22.86 by 22.86 cm, which results in a volume of 21 240 cm^3 or 0.02124 m^3. It is interesting to note that unlike breadboxes, no such standardization is apparent for the

BUSCON '91 East Product of the Year.

The competition will call us ruthless. You can call us at 1-800-234-4VME.

It's enough to make other VME board builders call us names. Or call it quits. A new 38 MIPS* VME single board computer based on the 88100 RISC microprocessor. Or a new 26 MIPS* VME board based on the 68040 CISC microprocessor.

Both are built by Motorola and offered at $3,995 each. That's just $105/MIPS for the RISC board, which compares nicely with the $1,000/MIPS you've been asked to pay for somebody else's board. And it's just $154/MIPS for the CISC board.

The MVME187 (RISC) and MVME167 (CISC) boards employ VME D64 architecture. And both come with four 32-bit timers.

Malcolm Baldrige National Quality Award

For a free color brochure, call the 800 number above. And see why the competition undoubtedly wishes we'd call the whole thing off.

MOTOROLA
Computer Group

Circle No. 15

Technically speaking

bread itself. The untimely arrival of store security interrupted the survey before an accurate weight could be ascertained.

Categorizing elephants is a more involved process. Because their size and shape vary immensely, a standard dimension is hard to arrive at. To make the matter even more complicated, there are two species of elephants: African and Asian. The African elephant, the larger of the two, stands approximately 4 meters tall at the shoulder and weighs in at 7500 kg.

These statistics point out a serious flaw in using elephants as a reference. The ceiling in most U.S. homes is 2.4 meters high, which means that *everything* inside a house is smaller than an elephant. (As children, we were permitted this oversight.)

The next logical step in this process would be to develop abbreviations for these and apply to have them adopted as standard units of measure. The standard volume of a breadbox, abbreviated bbox, and height of an elephant, abbreviated ele, could replace the cubic meter and meter as new standards.

While this may sound rather outlandish, there is precedent for the adoption of such standards. The English foot was originally derived from the length of a monarchical extremity, and horses are still measured in hands in parts of the world. While the American National Standards Institute has so far overlooked these popular units, it is hoped that they will devote the appropriate amount of attention to the issue in the future.

Sticks and stones

Almost every industry magazine these days seems to include an advertisement for a new calculator that far outstrips the last model introduced. Ones available today for under US $100 are more powerful than early calculating machines costing thousands of times more. But for all their sophistication, today's handheld number-crunchers are still but a stone's throw from their not-so-distant grandfather, the abacus.

The words *calculator* and *calculus* come from the Latin *calculus*, meaning a small stone or piece of lime. In prehistory, small stones were used as counters during voting and financial transactions. Placing the stones into special counting boards made it possible to execute more complicated functions, but transportability proved to be a problem. It was later discovered that replacing the rocks with beads on a string would make the apparatus portable, and so the abacus became one of the first handheld calculators.

When calculators are mentioned today, one thinks of something small enough to fit into a pocket, but it has not always been so. A headline from *Scientific American* in 1946 proclaimed: "Electronic calculator uses 18 000 tubes to solve complex problems."

ASICs (sic)

The proliferation of acronyms throughout the engineering profession has presented a number of interesting grammatical questions that are not routinely covered in textbooks. One frequent mistake involves the pluralization of acronyms.

The plural of any acronym such as ASIC, PLC, or DFT is best formed by adding a terminal s, always in lower case, to form ASICs, PLCs, or DFTs. Adding an upper-case S could lead to confusion as it may be taken for part of the acronym. (Only for acronyms such as BIOS, which already have a terminal S, should the plural be formed by appending 's to avoid confusion, yielding BIOS's.)

Some writers create plurals of acronyms by using apostrophes, but the use of an apostrophe implies a possessive form of the word. One would use an apostrophe when talking about an ASIC's voltage requirements, but not when discussing an order for 10 000 ASICs.

COORDINATOR: Kevin Self
CONSULTANT: Anne Eisenberg, Polytechnic University

Reflections

The bean counters

Once upon a time great ships of state sailed the seas of commerce. On the bridges of these great ships were the captains of industry, the wise and visionary leaders of that day. Many of them were engineers, who personally embodied a breadth of knowledge and wisdom that enabled them to navigate the murky waters unerringly toward the distant lands upon which their eyes were so firmly set.

Those were the days of yore—a legendary season in history when engineers were in charge. But now the mists of remembrance have all but closed over those times gone by. Today the stormy oceans of commerce are full of small and large boats sailing aimlessly under many different flags.

If you have visited the bridge of your boat lately, whom did you encounter there? Did the captain and mates have their eyes turned toward the still-unseen distant lands ahead? Or was their gaze instead cast downward upon the foaming whitecaps just beyond the bow? Or perhaps they were fixated not upon the sea ahead, but backward toward the boat's built-in wall safe. Were the captain and mates, perchance, wearing tell-tale, three-piece suits? If so, then you have met the new type of business leader—people who are guided only by the short-term accumulation of money. Since talking about money is crass, we call them bean counters.

In the days of old the crew of the ship would gather around the captain to listen to his tales of the great land beyond—the joys and benefits that would ultimately compensate for the hardships of the long voyage. The echoes of those wondrous tales still resonate about us, but those who tell them no longer abound. Now, should a passenger or crew member ask the captain about the final destination of the voyage, the same answer reverberates from boat to boat. "Wherever there are beans," intones the chorus of new captains. "But where shall we steer?" asks the crew, pleading for a motivating vision. "Toward the beans," comes the predictable wisdom from above.

"What happened to the wonderful land beyond that our old captain promised?" asks the crew. The captain frowns. "There were no beans there," he says in disgust. "He was court-martialed. We don't allow people like that to command boats anymore. Now get back to work."

The engineers have now been relegated to the engine room below deck, where there is no sunlight or any notion about where the great ship is headed. Still, they take great pride in the gleaming new engines, which they continually improve and polish. "Does the captain know the potential capabilities of our wonderful new engines?" asks one of the faceless engineers. An equally faceless companion looks up from her engine-software. "How could he?" says the software designer with resignation. "He has never been down here."

Dispirited, but determined, the engineers discuss among themselves the possible new lands that might lie out in the ocean, if only there were resources for certain improvements in the drive and navigation equipment. They decide to commission a small group to approach the august captain to plead for their plan. Unfortunately, the captain is too busy to meet with the engineers. He has a full calendar of appointments with various people who specialize in predicting bean crops. The humble engineers are not surprised; they had only expected as much. None among them had ever met the captain, though they had often seen his picture in the popular magazine *Beaness Week*.

An assistant to the first mate is delegated to meet with the engineers. He frowns his displeasure at their appearance—conspicuously sloppy in comparison with his own. Though he himself is only an apprentice bean counter, he keeps his shoes well-polished and his vest fully buttoned. Surely it cannot be long before he himself takes command of a ship. After all, he has a master's degree in bean administration from a great school with alumni in important positions throughout the bean economy. As for the dress of the engineers—what can you expect? They have spent too long in the engine room; they know nothing of the real world.

The engineers explain to the assistant their plans for an upgrade of the equipment of the engine room. The assistant is mildly amused at the computer-prepared charts that the engineers show. Typical, he thinks, even to the inclusion of several mysterious-looking equations that the engineers seem to think justify striking out in a new direction. His face set in an expression of impatience and concern, he daydreams until the engineers reach their final chart—a spreadsheet showing the accumulation of a future crop of beans.

Now he pounces on the hapless engineers. "You know nothing of beans!" he shouts. "The last time you made a proposal like this we had a crop failure! It was only through the efforts of our great new captain that we were able to obtain new bean seed. Even if your plans made sense (his expression is one of incredulity), you should know that there are insufficient beans in this year's allocation for your proposal. Furthermore, the harvest this quarter is down. This is not a time to bother the captain about such matters."

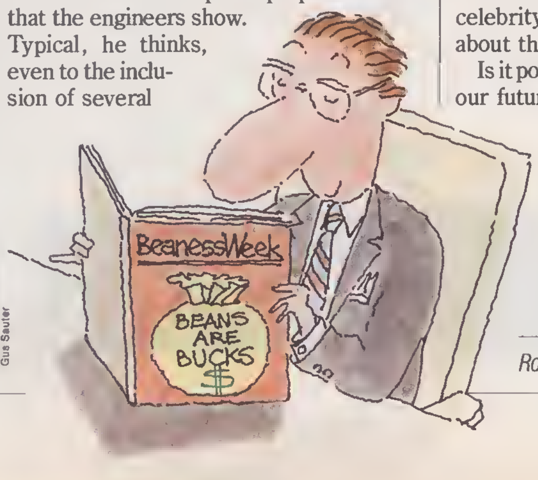
The engineers hang their heads in disappointment, remembering also the land that was sold, and the farm workers who were laid off. "Why does the world have to revolve around beans?" they think despairingly.

So ends the parable, but how has this turn of events come about? How could mere bean counters, ignorant of technology, take over complex, technologically oriented businesses? Perhaps there is a clue in Jerzy Kosinski's book *Being There*, in which an uneducated gardener, Chance, is struck by a car and suffers amnesia. Treated as an unknown savant by his benefactors, Chance meets the President of the United States. Chance is taciturn, but the President urges him to state his opinion of the current situation in the financial markets. Chance replies in the only terms he knows: "In a garden growth has its seasons," he says. "There are spring and summer, but there are also fall and winter. And then spring and summer again. As long as the roots are not severed all is well and all will be well."

Great wisdom is read into these words, and Chance, now Chauncey Gardiner, becomes a government advisor and a media celebrity, as he endlessly repeats homilies about the raising of crops.

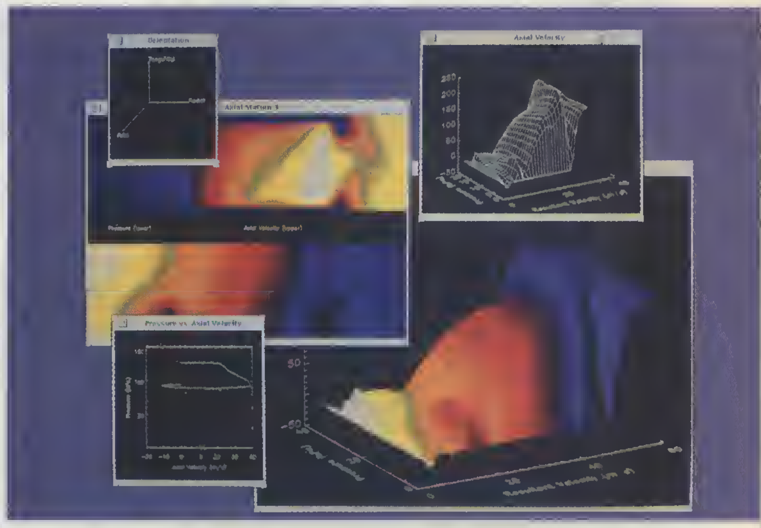
Is it possible that we engineers have ceded our futures to a rising legion of Chauncey Gardiners? Have we accorded too much wisdom and too much power to those who have the skills for tending a garden of beans? Or is counting beans a lot more important than engineering vision in the world today?

Robert W. Lucky



Gus Sauter

RAW. WELL DONE.



Attempting to analyze stacks of raw data can be frustrating if they can't be transformed into meaningful information that you can easily understand and use. Trends, relationships, insights, even breakthroughs, can remain buried unless you can unlock your data.

The key is PV-WAVE™ and The Visual Data Analysis Software from Precision Visuals.

PV-WAVE combines graphics with image processing, surface rendering, and animation, allowing you to visually analyze and interpret your data.

PV-WAVE™ TRANSFORMS DATA INTO DISCOVERY

"PV-WAVE gives me the power and flexibility of FORTRAN with the ease of use of my spreadsheet and a wide array of graphics capabilities."
Bill Estell
Analytical Engineer
United Technologies Hamilton Standard

With PV-WAVE, you can actually see your data, navigate through it, and display meaningful results. And, depending on your application, choose from point and click or command language versions for your Sun, DEC, HP, IBM, and SGI workstations and multi-user systems running UNIX, ULTRIX, and VMS.

If you're a scientist, engineer, researcher, or analyst who needs to turn raw data into well done results, call us today and ask about our no-risk, 60-day money-back guarantee!

Call Chris Logan today for your free video demo or evaluation copy of PV-WAVE.

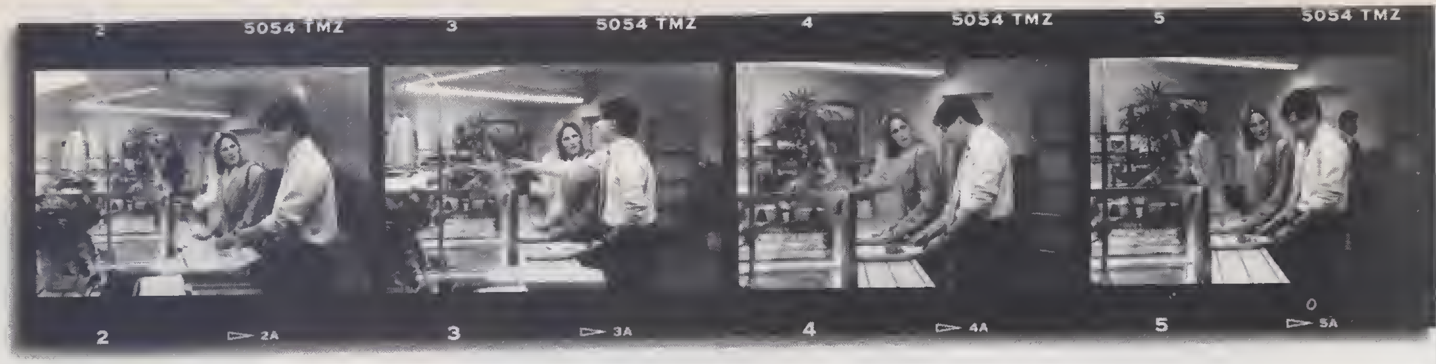
1•800•447•7147

PV·WAVE

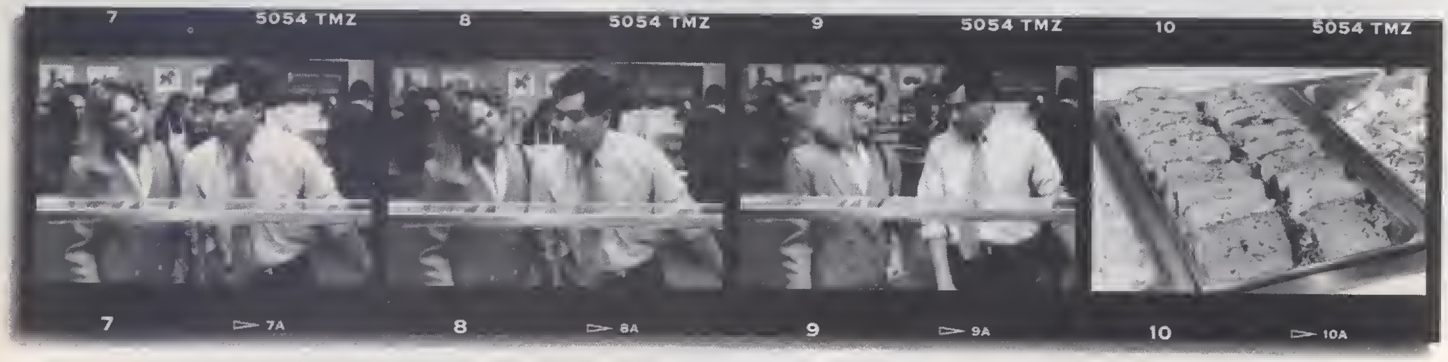
The Visual Data Analysis Software

Precision Visuals, Inc. 6230 Lookout Road Boulder, Colorado 80301 USA (303) 530-9000

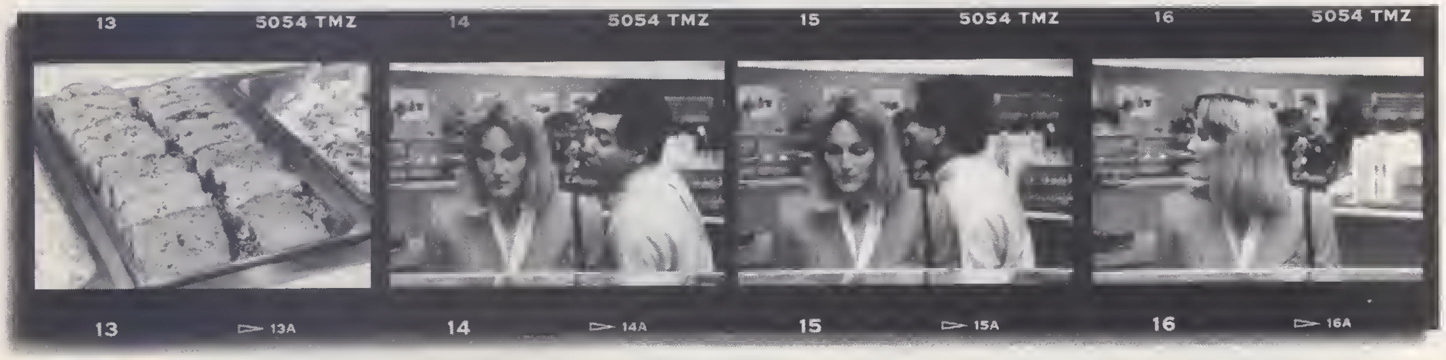
Circle No. 23



"So you're testing a prototype already?" *"Yep. Mmm, lasagne."* "Patents checked?"



"Wouldn't test otherwise." "Meet industry standards?" *"It'll comply...*



...which I don't think is true of the meatloaf." "Say, where're you getting so much help, anyway?"

The answer is in Dialog.

Information—complete, precise, up-to-the minute. It's your most powerful research tool. Find exactly what you need to know fast in Dialog,® the world's first and largest electronic library. We offer over 400 diverse, detailed databases readily accessible online via computer and modem, many even on compact disc. You probably won't have to look anywhere else. See your company's Information Specialist about Dialog. Or call for a free kit on Dialog information for your industry.

1-800-3-DIALOG

Outside U.S., 415-858-3785. Fax 415-858-7069.

Dialog Engineering Tools: Research and industry news for computers, electronics, energy, materials, and more. Plus patent, trademark, safety, regulatory, competitive data. Full text and/or abstracts from newspapers, newsletters, journals, proceedings, handbooks, encyclopedias. Some sources updated as often as daily, even continuously.

DIALOG INFORMATION SERVICES, INC.
A KNIGHT-RIDDER COMPANY

Q415

Circle No. 2

Spectral lines

MAY 1992 Volume 29 Number 5

Feedback

We owe our readers a report on the recent survey, "How are we doing?," published in the March issue.

We were particularly interested in how readers perceived the technical level of presentation of articles in *IEEE Spectrum*, since that is a benchmark question we've asked on previous, similar surveys. In 1985, 83 percent of respondents reported the technical level as just right, 10 percent as too technical, and 6 percent as not technical enough. In the current survey, 80 percent responded just right, 11 percent too technical, and 8 percent not technical enough.

We also asked about the breadth or scope of coverage. In 1985 the scope was seen as just right by 89 percent, but in the current survey that figure dropped to 80 percent.

The reason, we think, is that, with the erosion of advertising revenues by the recession, we've had to deliver a more limited menu of articles and subject matter over the past several months. For example, in 1985 *Spectrum* published more than 100 feature articles and 150 departments, while in 1991 those figures dropped to 75 and 110, respectively. Not surprisingly, several readers commented on the downsizing of *Spectrum*. One reader, observing the thinner issues, said *Spectrum* is not worth $100 per year (the cost is only $9 per year).

Nevertheless, the editors were pleased that the numerous comments made by readers who responded to the survey were largely very favorable. Citing a few (from dozens): "Your magazine is one of the few I look forward to reading cover to cover. . . A well-written, balanced magazine." "*Spectrum* is outstanding. Treatment of current issues is thoughtful and compelling. As a weapons/aerodynamics/systems/supercomputing professional, *Spectrum* is a joy to read." "Just keep on doing what you're doing! The technology keeps me current. The articles on technology policy are informed, thoughtful, and objective."

As we had hoped, some readers had suggestions for improvement.

One reader liked the topics covered in special issues but urged more independent analysis and evaluation. Another suggested more articles dealing with "how one discipline relates to another, systems thinking, and increasing creativity." Many readers, noting they've become too specialized, urged that more space be devoted to tutorial and "basic explanations" of material outside their immediate fields.

Proving that what is one engineer's meat is another's poison, while many readers rated the issue on the Gulf War highly, one labeled it "political crap." Likewise, while another called for more interviews with executives and Government officials, still another called for less reliance on Government and corporate spokesmen.

Many readers agreed on one point—that we ought to find more space for letters, a traditionally popular element in the magazine.

As we continue to process the returns from the survey, we'll bring you additional results.

Milestones

Avid masthead readers will have noticed the recent disappearance of a name from its usual position, and the addition of some new ones.

Ronald A. Jurgen retired in January after a 28-year career with *IEEE Spectrum*. An electrical engineer who received his degree from Rensselaer Polytechnic Institute in Troy, N.Y., after serving in the Navy as an electronics technician in World War II, Ron's publication experience included a stint with *Electronics* magazine. He later became managing editor of *Electrical Engineering*, the flagship publication of the American Institute of Electrical Engineers.

Readers of *Spectrum* will recall Ron's stewardship of the annual January review of technology, which we began in 1974. Ron is an expert on automotive electronics, and covered many of the annual new car introductions in Detroit. He also participated in 40 consecutive Consumer Electronics Shows, something of a record, we believe. He served as issue editor for a special *Spectrum* issue on data-driven automation, for which he received a John D. Ryder Communicator of the Year Award. And he was editor of a Spectrum Series IEEE Press Book, *Computers and Manufacturing Production*.

Ron will continue as a contributing editor to *IEEE Spectrum*.

In June, another veteran's name will disappear from our masthead. Executive Editor Edward A. Torrero will be pursuing new avenues of interest.

Ed got his start in journalism in 1971 as solid-state editor for *Electronic Design*, covering the then-emerging world of microprocessors.

Before that, Ed acquired design experience at Wheeler Laboratories and Sedco Systems. He was also a research fellow at the Polytechnic Institute of Brooklyn and a first lieutenant in the U.S. Army Corps of Engineers. He earned his BEE from the City College of New York and his M.S. in electrophysics from the Polytechnic Institute of Brooklyn.

During his nearly 16 years with *Spectrum*, Ed's dogged determination helped launch many new projects, including the Spectrum Series of IEEE Press Books and the Japanese edition of *Spectrum*, as well as our program for editorial interns.

We hope that as Ed finalizes his plans, he may find time to assist us occasionally.

As Ron and Ed leave us, two new members join the staff. Both are electrical engineers and experienced journalists. Richard Comerford was executive editor of *Electronics Test* magazine. He earned a BEE from Manhattan College and worked with the Systems Management Division of Sperry (Unisys).

Michael Riezenman is a former managing editor of *Electronic Design*. He earned his BSEE from the Massachusetts Institute of Technology and was an engineer with ITT Defense Communications.

Richard and Mike previously contributed to *Spectrum*, so we know them well, and welcome them as full-time staffers.

Donald Christiansen

ICs going on a 3-V diet

After over a decade at 5 V, higher IC densities require a 'cooler' 3-V standard, with transitional systems likely to mix 3 and 5 V

High above the clouds, with several more hours to fly and a deadline to meet, the engineer was just getting to the critical calculations for the starship engine design when on went the lo-bat light on his portable computer. He reached for his extra battery pack and then–"Rats!" he thought, "There goes my promotion. If only I hadn't decided the spare was too heavy to lug along!" Resigned to his fate (and having left his copy of *Spectrum* behind, too), he pulled the flight magazine from the rack and idly flipped its pages as he stared vacantly into his empty future.

Exaggerated though it is, that scene and variations on it are driving the computer industry to adopt a supply voltage lower than the current standard of 5 V. Not only can reducing the operating voltage of electronic components extend battery life, it can also help make portable equipment smaller and lighter. Moreover, it can enhance reliability by enabling components to run cooler despite the trend toward increasing operating frequency. And it is essential if semiconductor geometries are to go much below 0.5-μm channel lengths and 10-nm dielectric thicknesses.

But before a new industry standard for IC operating voltage can be adopted, it must be defined. In addition to the supply level, interface levels—the high and low logic voltages on the input and output pins—must be specified. System considerations must be taken into account. Finally, the result must be incorporated in a document put out by a recognized standards organization.

SYSTEM-LEVEL CONSIDERATIONS. Size, weight, and battery life—all selling points among battery-operated systems like palmtop computers—are contingent on the drain on the battery pack [Fig. 1]. If the power drain is low, the same battery will last longer or a smaller battery will last as long as a larger one did before. One simple way to reduce that drain is to lower the operating voltage of the ICs in the system. Even taking the needs of the display and disk drive into account, that can slash 30 percent of a portable computer's overall power consumption.

The effects of lowering the voltage can be impressive. A computer system operating at 5 V commonly takes five 1.5-V alkaline primary (throw-away) batteries or five 1.2-V nickel-cadmium (NiCd) secondary (rechargeable) batteries. By contrast, a 3.0- or 3.3-V system takes only three batteries, reducing the weight of what is often the heaviest component in the system by 40 percent. If the voltage is further reduced to about 2.4 V, another battery can be eliminated, for a total saving of 60 percent. It has been estimated that battery-operated systems designed for 5-V operation will run three to four times longer on the same charge if powered by 3 V. The penalty will be a reduction in speed of up to 50 percent.

Battery-operated portable equipment is only one of the areas in which lowering IC voltages looks attractive. Workstations today use 50-MHz processors. By 1993 or 1994, 100 MHz will be the norm, and 500 MHz or higher will be common by the end of the decade. Since the power consumed in operating a computing system is proportional to the system's clock frequency, heat generation is becoming an issue, as it may rule out the use of low-cost plastic packaging and increase the need for fans and other cooling apparatus. Eliminating those noisy and failure-prone components not only saves money, it boosts system reliability as well.

For workstation ICs, lowering the voltage is not as simple as running a 5-V device on 3 V. That would reduce the clock frequency, which is acceptable in many portable-computer applications but not in workstations. What workstations need are ICs designed from the outset for operation at the lower voltage.

The growing size of memories in all classes of computer also pushes up power consumption. Windowing environments and other advanced human-interface features like speech and handwriting recognition (for pen-based systems) demand prodigious amounts of memory and increasingly powerful microprocessors. That demand is being filled not by multiplying the number of memory devices in a system but by putting more memory into each device.

A modern hundred-thousand-gate microprocessor or gate array can have millions of transistors tightly packed on a single silicon chip. The heat of those rapidly switching transistors not only affects reliability, it can raise the operating temperature above the rating of low-cost plastic packaging, forcing a move to more expensive and heavier cer-

Betty Prince Texas Instruments Inc.
Roelof H.W. Salters Philips Research Laboratories

 0018-9235/92/$3.00©1992 IEEE

amics. The heat generated is proportional to the square of the voltage applied to the ICs.

A still bigger problem with high-density systems is posed directly by the supply voltage. More than 16 million transistors now crowd onto chips not much larger than the one-million-transistor memories of five years ago. That 16-fold increase is accomplished by scaling the MOS storage transistors both laterally and vertically.

Lateral scaling affects the channel length, which below about 0.5 μm runs into trouble. At that point, applying 5 V across the transistors degrades performance and reliability. Although those effects can be mitigated by redesigning the transistors, reducing the voltage to 3.3 V permits reliable performance down to a channel length of about 0.4 μm. Vertical scaling involves thinning the silicon dioxide layer used for the MOS gate dielectric. Too thin (10 nm or so) and the dielectric can no longer sustain an applied 5 V.

Various techniques have been developed for creating high-density devices that will work with 5-V supplies at no loss in reliability. They can be categorized as most appropriate at the transistor, gate, or chip level.

At the transistor level, grading the ionization (doping) of the source and drain junctions of the MOS transistor lets it sustain a higher voltage. The use of such graded-junction transistors has permitted circuits with geometries down to 0.7 μm to be used reliably with standard 5-V supplies. For example, 1M-bit and 4M-bit dynamic RAMs (DRAMs) remained at 5 V, in part because of such methods.

At the gate level, additional transistors can be added in series to reduce the voltage across any single transistor. Both this method and the graded transistor may be used with logic and microprocessor ICs as well as with memories.

At the chip level, at least for memory devices, voltage converters may be stationed at the periphery of the chips to shift between the applied 5 V and a lower voltage for the internal memory array. That secures some of the density and power benefits of the lower voltage for the array while still presenting a 5-V interface to the external world.

The first generation of 16M-bit DRAMs, now on the market, employed that technique. Their 0.5-μm internal arrays are powered by about 3 V even though the circuitry around the chip periphery operates at 5 V. The next generation of 16M-bit DRAMs will reduce power consumption and chip size by operating only at 3.3 V.

Processors, high-density logic, and gate arrays, however, resist simple solutions like on-chip voltage converters because they are not readily segmented into sections that can be isolated. In general-purpose logic, the applied voltage needs sustaining on every transistor. Thus, for high-density devices of that type, a lowered external voltage is required.

LOWER THE VOLTAGE. But all the problems mentioned so far are solved if the operating voltages of computer systems and the ICs in them are reduced. Since the market in electronic computer systems is large, diverse, and international, doing so will require both international interface standards and nearly simultaneous large-scale production of all the diverse 3-V components that will be used in such systems.

With any luck, a complete complement of 3.3-V digital ICs will be available by 1993 or 1994

There are standardization issues for both the power supply voltage applied across the individual components and for the signal voltages that interface them with one another. The supply-voltage standard will depend strongly on whether the system is powered by a regulated power supply or an unregulated battery.

All line-operated computer systems and even some high-performance battery-operated units (like electronic organizers, laptop and notebook computers, portable compact discs, language translators, and portable digital audio tape systems) are regulated. As early as 1984, the U.S. Joint Electron Device Engineering Council (Jedec) adopted 3.3 V ± 10 percent for the supply voltage in line-driven regulated systems (JESD 8.1) and battery-operated regulated systems (JESD 8.0).

In addition, the Jedec JC42.3 RAM Committee has gone on record as supporting a 3.3-V, 10 percent power supply for 64M-bit dynamic RAMs and 16M-bit static RAMs. More recently, the JC16 Low Voltage and Electrical Interface Committee of the Jedec has agreed on a revision to the JESD 8.1 standard; this revision maintains the 3.3-V, 10 percent voltage levels for systems with TTL-type interfaces operating from regulated supplies.

Since more than 60 companies worldwide have been cooperating in the JC16 low-voltage standardization effort, it is likely to enjoy widespread support. As a result, 3.3 V at 10 percent now seems sure to be the standard for medium-speed systems with regulated supplies that are descended from CMOS and bipolar components with TTL-type interfaces.

Unregulated battery-powered systems frequently have supply-voltage tolerances in excess of 10 percent to accommodate the wide range of battery voltage encountered over a charge-discharge cycle. To access the lowest part of the battery discharge cycle, and to use the available battery energy more efficiently, the IC specification is often extended down from 3.0 to 2.7 V or even lower. Speed of course falls off. But after all, it may be better to have a palmtop computer run slowly than not at all when the batteries have sunk to the 2.7-V level.

The high end of the voltage range used for battery-operated components has been specified by various manufacturers at anywhere from 3.6 to 5.5 V or even higher. Many battery-operated components specified from 2.7 to 5.5 V are already on the market, chiefly for handheld computer-like devices like smart memo pads, telephone dialers, and dictionaries.

Recently, the development of high-density ICs with a maximum voltage rating of 3.6 V has been announced by several companies for battery-operated systems. Hitachi, for example, has said that it is working on 1M-bit and 4M-bit pseudostatic dynamic RAMs (DRAMs) that will operate in the 2.4–3.6-V range. The chips are intended for use in memory-intensive battery-operated equipment like palmtop PCs.

The last year saw the introduction of several palmtop PCs that use components specified for that range. The computers can function for weeks on ordinary AA batteries, running spreadsheets and word-processing programs. Many can exchange data with desktop PCs.

Early battery-operated systems with ICs specified for even wider ranges of operating voltage have been around for years in such apparatus as telephones and hearing aids. Those early low-performance ICs were primarily designed in CMOS and operated from 1.5 to 5.5 V or from 2 to 6 V.

The Jedec Standard JESD 8.0 dating from 1984 governs standard voltage ranges and interfaces for those battery-operated components. An update for the standard from the JC16 Jedec Committee has been projected following the recent update of the JESD 8.1 for regulated power supplies.

Defining terms

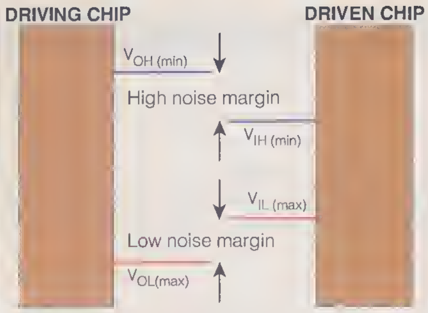
Operating voltage: the voltage at which a circuit element operates. This may or may not be equal to the voltage supplied to the chip.

Primary cell: a cell that produces electric current by means of irreversible electrochemical reactions; hence a cell that cannot be recharged. Some primary cells are reversible to a limited extent.

Secondary cell: a cell that produces electric current by means of reversible chemical reactions; hence a cell that can be recharged.

Supply voltage: the voltage supplied to a chip from an external power source.

[1] Portable gear like this PalmPAD computer from GRiD Systems Inc. will benefit greatly from low-voltage ICs. The technology can be used to shrink the computer, lengthen the life of its battery, or both.



[2] The interface levels listed in Table 1 are most easily comprehended when they are defined graphically. VOH_{min} is the lowest voltage that the driving chip will put out as a logic 1, and VIH_{min} is the lowest input voltage that the driven chip will recognize as a logic 1. Similarly, VOL_{max} is the highest voltage that the driving chip will put out as a logic 0, and VIL_{max} is the highest voltage that the driven chip will recognize as a logic 0.

Also requiring standardization is the largest supply voltage that can be applied to the chips for a short time without damaging them. The absolute maximum voltage specified for MOS ICs is usually whatever will, if applied for a specified period of time, still permit the chip to function within specification for a 10-year life. That maximum is determined by either the channel length of the MOS transistor or the thickness of the gate oxide dielectric.

The older 1984 Jedec Standard 8.1 specified an absolute maximum of 5.5 V to be applied under controlled conditions so that the 3.3-V components would be able to interface with older 5-V TTL components in a system. That allowed designers to mix 3.3- and 5-V components in a system with little risk of damaging the lower-voltage components.

To build a high-density 3.3-V IC capable of withstanding 5.5 V, special protective circuitry must be added. That addition both reduces the performance of the circuits and increases their die size, thereby increasing their price.

The 5.5-V upper limit in the 1984 version of the JESD 8.1 standard reflected the expectation that the first 3.3-V components would appear long before sufficient part types were available to configure a complete system. It now appears that the transition period will be quite short—a year, perhaps. In response, the recent revision of the JESD 8.1 standard by the JC16 Jedec committee lowered the absolute maximum voltage rating to 4.6 V.

INTERFACE CONSIDERATIONS. In addition to standardizing the power supply level, the dc voltage levels at the input and output pins must be specified [Fig. 2]. Low-voltage interfaces fall into three main speed-dependent performance categories: low, medium, and high. Low-performance components generally run below 10 MHz and often are powered by unregulated batteries. Medium-performance parts tend to be TTL-type devices running between 10 and 100 MHz. High performance refers to advanced microprocessors running at speeds in excess of 100 MHz.

Low-performance components are typically made in CMOS technology since its outputs can swing from rail to rail and its inputs are normally specified as a fraction of the power supply voltage, which defines the input characteristics over a wide range of voltages. The lower performance of the CMOS interface is due to the time the outputs take to swing between power and ground.

TTL interfaces, which can be made in bipolar or CMOS technology, are considered higher performance than full-swing CMOS interfaces because of their limited output swing. Historically, the limits for 5-V power supplies were a maximum of 0.4 V for the low output level and a minimum of 2.4 V for the high one. The TTL interface has also historically specified input voltage levels of 0.8 V for the low-level input maximum and 2.0 V for the high-level input minimum. The recently passed 3.3-V ''Low Voltage TTL'' standard agreed by the Jedec JC16 Committee retains those values [Table 1].

Interfaces for high-performance systems are also needed. Several options for low-swing, high-speed interfaces have been available in the 5-V range—emitter-coupled logic (ECL), for example. Recently various papers have been presented on circuit techniques for achieving a lower-voltage ECL interface. ECL-compatible interfaces have been implemented in both bipolar and CMOS technologies. An ECL-compatible CMOS circuit with a 0.5-μm minimum feature size may possibly even operate at 1 gigabit per second. Also, for the 3-V range, Gunning transceiver logic (GTL), which was developed by Xerox, has been widely used.

TIMING IS EVERYTHING. With any luck, a full range of 3.3-V IC components will be available by 1993 or 1994, and designers of low-voltage systems will find themselves forced to mix 3.3- and 5.0-V parts for only a short time. Microprocessors designed for 3.3-V operation have been announced by suppliers like Intel, Motorola, and American Micro Devices. In addition, Texas Instruments, Signetics, and others have indicated the availability of 3.3-V ACT logic lines. And AT&T has announced a 3.3-V standard cell library for battery-operated systems that includes rail-to-rail outputs.

The emergence of sophisticated design systems for application-specific ICs (ASICs) has shrunk the time between the first appearance of DRAMs, which drive the technology, and ASICs built in the same tech nology. So high-density logic chips could fol-

Battery basics

Both primary (throwaway) and secondary (rechargeable) batteries are widely used today for powering portable equipment and also for memory backup in line-powered computers. Alkaline cells are the most popular type of primary battery, followed by lithium. Nickel-cadmium cells dominate the rechargeable market, although nickel-metal hydride (NiMH) devices look attractive for the future because they use no toxic cadmium.

As a rule, primary batteries store more energy per unit weight than secondary units although the latter typically can deliver more peak power. Primary batteries are the usual choice for memory backup, an application that seldom requires much in the way of power.

Except for the lithium cells, which have a nominal voltage of about 3 V, the voltages for all the batteries under discussion range from about 1.6 V when fresh down to about 0.8 V when depleted. Batteries of cells are used when higher voltages are needed.

For systems that cannot tolerate it, the 2:1 voltage ratio of raw battery power can be regulated, most often by a step-up switching converter, to a stable level. Secondary batteries tend to have flatter discharge curves than primaries and therefore are not always regulated. When regulated, however, they tend to be stepped down as, for example, in a notebook or laptop computer.

In that case, a typical system will have six NiCd cells connected in series to give a maximum fully charged voltage of 7–9 V, which is then stepped down to 5 V. In a handheld or palmtop computer, by contrast, two primary alkaline batteries are often connected in parallel and stepped up to the 3.0–3.3-V operating range required by their internal ICs.

Since weight reduction matters in portable systems, there is a push to reduce the number of cells needed in a system. Since the individual cell voltage is dictated by the cell chemistry, cutting the number of cells (in an unregulated system) will necessarily reduce the supply voltage. Low-voltage ICs thus have a lot to contribute to the weight-reduction effort. Of course, that contribution will only be realized if the IC's current drain remains the same as the voltage is being reduced, but this seems to be the case.

BATTERY TRENDS. The NiCd rechargeable battery has been around for 25 years. From 1970 to 1990, the nominal capacity of a NiCd AA cell about doubled—from 400 to 800 milliampere-hours, with some specialty units going even higher. While the sealed NiCd will undoubtedly remain popular for some time to come, it will see competition from NiMH cells, which have nearly the same characteristics but without the environmentally troublesome cadmium. A NiMH battery has greater capacity than a high-capacity NiCd, and the new type also has somewhat less of an overcharge potential. It will, however, probably remain a more expensive option for the near future.

A battery-related issue that has yet to be resolved is the problem of interfacing a pair of battery-powered systems. Good engineering practice dictates the assumption that one system has a fully charged battery while the other's battery is nearly depleted. The problem is to ensure that the ICs in one system will be able to recognize a high and low level from the other—a challenge with unregulated batteries.

low the 0.5-μm 16M-bit DRAMs onto the market within less than a year. If so, many suppliers should avail themselves of the opportunity to move to the denser technologies, which cannot support 5-V levels.

In an odd technological twist, DRAMs may lag logic products in the 3-V range. The reason is that many early 3.3-V logic products are based on older technologies that can support 5-V power supplies but have been recharacterized for the 3-V range.

DRAMs, on the other hand, are less easily transmogrified. A 5-V DRAM stores data in capacitors that are fully charged at 5 V, and 3 V could leave insufficient charge in the cells. Many DRAM manufacturers have therefore chosen to delay announcing low-voltage parts until their new 3.3-V designs are ready rather than entering earlier with recharacterized components that may disappoint their customers. By the time the second-generation 3.3-V 16M-bit DRAM is in full-scale production in 1993, a full range of 3.3-V support components will be on the market, and systems for that voltage will be under development.

1. DC voltages of IC interfaces*

Voltage	Logic type: Regular CMOS	Regular TTL	Low-voltage CMOS[a]	Low-voltage TTL[b]
V_{CC}	5.0±10%		3.3±10%	
Minimum high output, $V_{OH\,(min)}$	$V_{cc}-0.1$	2.4	$V_{cc}-0.1$	2.4
Minimum high input, $V_{IH\,(min)}$	$0.7V_{cc}$	2.0	$0.7V_{cc}$	2.0
Maximum low output, $V_{OL\,(max)}$	0.1	0.4	0.1	0.4
Maximum low input, $V_{IL\,(max)}$	$0.3V_{cc}$	0.8	$0.2V_{cc}$	0.8

* For regulated power supply operation. All values in this table are in volts.
a According to standard 8.0 (1984) of the Joint Electron Device Engineering Council (Jedec).
b According to the recent revision to Jedec standard 8.1 passed by the Jedec JC16 committee.

2. Low-voltage IC technology projections

Technology	Year: 1992	1994	1996	1998	2000
Channel length, μm	0.5	0.4	0.3	0.2	0.1
Dynamic RAM					
Bits, Mb	16	64	64	256	256
Supply voltage, V	3.3/5.0	3.3	2.5	2.5/3.3	2.5
Logic					
Gates × 1000	200	400	600	1000	2000
Supply voltage, V	3.3	3.3	2.5	2.5	1.5
Processor speed, MHz	50	100	150	200	500

The critical factor now seems to be subsystems, such as hard disks and displays, that look like having difficulty running at the lower voltage. Although low-voltage disks are being developed, the solid-state disk is probably more promising in the long run. Speeding the conversion to solid-state technology may well prove to be the best solution here.

While 3.3-V components should be available in enough variety not to need being mixed with 5.0-V parts in a single system, systems will not all convert to 3.3 V overnight. The low-voltage systems will have to communicate with 5.0-V systems, requiring logic capable of making the voltage conversion. The mixing problem, therefore, is still foreseen, but at the system level.

The general sense is that the 3.3-V era began in late 1991 with many component announcements. The general utilization of those components in systems designed especially for them will probably become commonplace in 1993.

LONGEVITY. As technology drivers, DRAMs herald the capability of process technology. Early 4K-bit and 16K-bit DRAMs operated off a 12-V supply. The 64K-bit, 256K-bit, 1M-bit, and 4M-bit memories used 5 V, which was suitable for geometries down to about 0.7 μm. The first-generation 16M-bit DRAMs ran off 5 V, converting it on chip for the 0.5-μm memory cell arrays; but later generations of the 16M-bit device should omit the voltage converters and run at 3.3 V.

The 64M-bit and first-generation 256M-bit DRAMs can retain an external 3.3 V with converters producing 2.5 V for the memory arrays. The limiting geometry for reliable 3.3-V performance may be about 0.4 μm; it is also the technology of the first-generation 64M-bit DRAM. Therefore, for the sake of reliability as well as the power savings of eliminating the voltage converters, the industry may decide to go below 3.3 V for the second-generation 64M-bit DRAM [Table 2].

In all likelihood the 3.3-V standard will last for at least three technology generations. These occur about three years apart and last for about nine years in production. If the first 3.3-V parts on the market in 1992 are in the 0.5-μm technology of the 16M-bit DRAM, as seems likely, then these three generations will be the 16M-, 64M- and 256M-bit DRAMs. Since the first-generation 256M-bit DRAM may well be introduced in about 1997 and stay in production to about 2003, the new 3.3-V standards could last at least 10 years.

At the same time, the power requirements of battery-operated systems may drive semiconductor manufacturers to offer 2.5-V versions of the 64M-bit and then the 256M-bit chips as early as 1995. Now, once the number of batteries is reduced to three, the obvious thing is to reduce it to two and then one. The assumption here is that users will want to power their systems with 2 and then 1 V. Looking forward to that eventuality, Fujitsu has already produced a technical description of a 256K-bit full CMOS static RAM that operates down to 1 V, and Hitachi has described a 1.5-V DRAM also for battery-based applications.

TO PROBE FURTHER. The best sources of information on Jedec IC voltage standards are the standards themselves, which are published by the Joint Electron Device Engineering Council, 2001 I St., N.W., Washington, D.C. 20006; 202-457-4997, and available from Global Engineering Documents, 2805 McGaw Ave., Box 19539, Irvine, Calif. 92714; 800-854-7179. Standards 8.0 and 8.1, which were most recently revised in 1992, cover battery-operated and line-operated systems, respectively.

The digest of technical papers for the 1991 VLSI Symposium on VLSI Circuits sponsored by the Japan Society of Applied Physics and the IEEE Solid-State Circuits Council has two papers that hint at the shape of things to come. One, "Quasi-Complementary BiCMOS for Sub-3-V Digital Circuits," by Kazuo Yano, Mitsuru Hiraki, Shohji Shukuri, Yasuo Sawahata, Mitsuru Hirao, Nagatoshi Ohki, Takashi Nishida, Kohichi Seki, and Katsuhiro Shimohigashi describes a new BiCMOS circuit for the low-voltage deep-submicrometer regime. The other, "1-Gbps Pure CMOS I/O Buffer Circuits," by Manabu Ishibe, Shoji Otaka, Junichi Takeda, Shigeru Tanaka, Yoshiaki Toyoshima, Satoru Takatsuka, and Shoichi Shimizu, presents very high-speed I/O circuits, which can eliminate the I/O speed bottleneck common to most CMOS circuitry. The digest is available from the IEEE Service Center Single Publication Sales Unit, 445 Hoes Lane, Piscataway, N.J. 08854. Japanese readers can obtain it from the Business Center for Academic Societies Japan, 23-1, Hongo 3-chome, Bunkyo-ku, Tokyo 113, Japan.

ABOUT THE AUTHORS. Betty Prince is new products manager, worldwide memory marketing, at Texas Instruments Inc., Dallas. She has worked in semiconductor memories for most of her professional life, having held marketing positions with Motorola Inc. and Philips before joining TI in 1990. She founded the Jedec JC16 Electrical Interface Standards Committee, and chaired it from 1989 to 1990.

Roelof H.W. Salters is chief scientist at Philips Research Laboratories, Eindhoven, the Netherlands. He has worked in circuit design, mainly digital logic and memory circuits, during most of his career. He has been with Philips all his professional life, spending a number of years with Signetics Corp., Philips's U.S. affiliate. He is currently a task group chairman in the Jedec JC16 committee on low-voltage standards. ◆

ASIC testing upgraded

The demand for quality parts in short development times is forcing digital ASIC designers to use nontraditional test methods

While ASIC density and complexity have exploded in the last five years, global market pressures have if anything increased the demand for both quality and quick turnaround. By now, testing accounts for nearly a third of the ASIC development cycle. Yet private studies conducted for Sun Microsystems Inc., Mountain View, Calif., show that one in three ASIC defects that surfaced after testing might have been caught had the right tests been used.

Thus the way in which ASICs are tested can determine whether a project, or a company, succeeds or fails. As a result, engineers are turning to nontraditional test techniques—scan design, built-in self-test, and massive observability—to cost-effectively ensure ASIC quality, especially for designs with 50 000 or more gates.

What is needed for choosing the correct design and test options is a complete economics model. Though such economic factors as test pattern generation and test hardware costs are often considered, the time-to-market and quality costs associated with testing are often overlooked.

ASIC TEST ECONOMICS. The less structured the test methodology, the larger the portion of the development schedule it consumes [Fig.1]. And time is truly money; studies by McKinsey & Co., New York City (*McKinsey Quarterly*, spring 1989), have shown that being a few months late to market with a product is even worse than having a 30 percent development cost overrun. If using a particular test methodology can get a product to market faster, then the extra revenue and profits can offset any cost it adds.

The Fig. 1 time-to-market model shows the difference in revenue when a product is on time or late. The model assumes that there are three market stages: a growth phase (where sales increase at a fixed rate, whether a product is early or late), a stagnation phase (where sales level off), and a decline phase (where sales decrease to zero).

Marc E. Levitt Sun Microsystems Inc.

The model shows that a delay causes a significant decline in revenue. Suppose a market has a six-month growth period followed by a year of stagnation and a decline to zero sales in eight months; then being late to market by three months would reduce revenues by 36 percent. Thus a delay of one-eighth of the product lifetime reduces revenue by over one-third. Such a loss can be especially severe since the largest profits are usually realized during the growth phase.

QUALITY COSTS. Quality, the other major cost area, must also be included in any cost-benefit analysis. An oft-cited rule of thumb is that the cost of finding a defective component goes up by a factor of 10 for each level of assembly—device, board, system, and field installation—and recent studies by Sun Microsystems have indicated that 10 may be too small a multiplier for modern electronic systems.

Whatever the number, low-priced, low-quality parts may cost more than expensive high-quality devices when the costs of downstream fault detection and correction are factored in. With a fault coverage of only 60–75 percent, 2 percent of the devices that pass test can be defective (as is common with many ASICs that have little or no testability built in). Finding those defective devices later can easily drive up the real cost of the device by 20 percent (or more).

> Being a few months late to market with a product is worse than having a development cost overrun of 30 %

Considering the cost benefits, one might wonder why ASIC test is not more thorough. The answer involves four key factors. The most significant is the sheer complexity of today's ASICs, which defeats traditional device-testing methodologies. Another is that, unlike standard parts where the total test cost and development time can be amortized over millions of devices and a long product life cycle, the low volumes and rapid turnaround of ASICs do not justify a similar expenditure of effort.

Yet another factor exacerbating the testing problem is that ASICs are designed by product or system engineers, not by IC specialists familiar with potential device problems. Lastly, the relationship between the ASIC supplier and the designer often precludes the development of tests *after* the latter has delivered the design to the foundry, adding to the design workload.

In addressing these problems, the industry must find solutions that yield high productivity and a quick turnaround time without sacrificing quality. Luckily, many such techniques are becoming available to the ASIC community. The accompanying table lists these techniques along with their pros and cons. Bear in mind that the correct approach for a particular design may not be a single testing methodology, but a combination of two or more.

REQUIRED TESTS. The tests most critical to the ASICs' success, and those that require the most developmental effort, are the functional ones. Their goal is to ensure no defects exist that can cause a chip to malfunction; their thoroughness in checking for any defects will ultimately determine ASIC quality.

Functional test development can be approached from two directions. On the first, or behavioral, path, testing aims to exercise the ASIC in the same way it would be used in a system. When the other, nonbehavioral, route is followed, the tests developed check to see that each logic element and interconnection performs its defined function, regardless of how the device will be used.

In developing behavioral tests, one generally starts with the simulation vectors used by the designer to check the logic design. To establish how good these vectors are at finding faults—their fault coverage—engineers use fault simulation, in which the vectors are run through a computerized description of the design into which faults have been injected.

The injected faults are typically modeled as stuck-at conditions, where the output of a logic element remains constant (stuck-at) regardless of its inputs. In CMOS circuits, for example, a stuck-at-1 fault represents the condition when the output is inadvertently connected to power, while a stuck-at-0 fault occurs when the output is grounded.

For a number of reasons, behavioral test-

 0018-9235/92/$3.00©1992 IEEE

1. Advantages and disadvantages of various ASIC test approaches

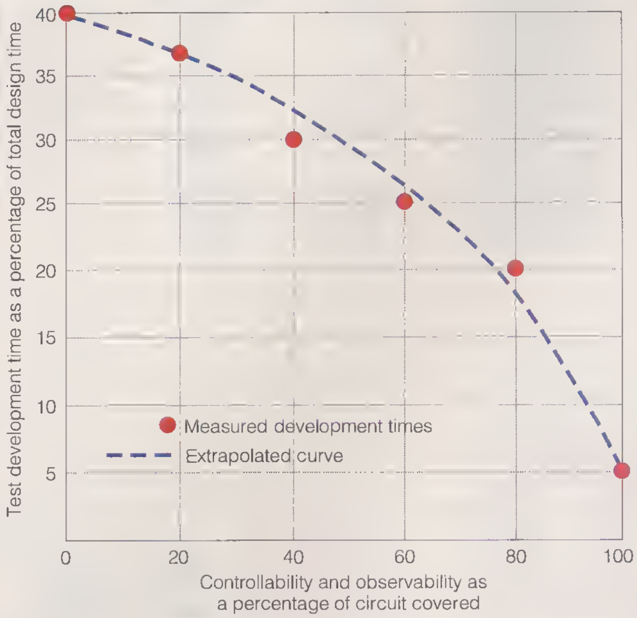
Test method	Advantages	Disadvantages	Comments
Behavioral	No silicon overhead; works for all designs	Test patterns must be created manually; requires fault simulation to determine fault coverage; takes a long time to improve fault coverage, if improvement is possible	Should only be used on designs/logic blocks with under 10 000 gates; fault diagnosis is low
Ad-hoc testability techniques	Low silicon overhead (<5%); minimal performance impact	Test patterns must be created manually; requires fault simulation to determine fault coverage; no CAD tools support	May not reduce test development time; good for highly structured design
Full scan	Highly structured; good ATPG available; high fault coverage; automatic test-logic insertion; well-supported and understood	Works for synchronous logic only; scan storage elements are larger and slower than non-scan equivalents; test is serial; medium silicon overhead (5–15%)	Numerous variations and CAD tools available; supported by many ASIC vendors; difficult but not impossible to use for at-speed and non-stuck-at testing
Partial scan	Less silicon overhead (1–15%) and performance impact than full scan; user-definable test/DFT goals; allows partitioning by best test method	Test vectors take longer to develop than full scan; fault coverage and area overhead are unknown until design is finished; translation of vectors to tester is difficult	Some ATPG tools are available; can revert to full scan under certain conditions; many ASIC vendors have no support yet
Built-in self-test (BIST)	Executes at system speed; no complex external tester; can significantly reduce lifetime test costs	Requires scan foundation for random logic testing; highest silicon overhead (10–40%)	Excellent for memory testing; can be used in field test and diagnosis; some ASIC vendor support
CrossCheck (massive observability)	Also handles asynchronous circuits; does not require design-in effort; low performance impact; tests for non-stuck-at faults; fast simulation and fault diagnosis	Does not work at speed; only available from licensed vendors; relatively high silicon overhead (15–25%); not all vendors handle embedded memory	Technology patents are the property of CrossCheck Technology Inc., San Jose, Calif.
I_{DDQ} (massive observability)	High fault coverage; tests for non-stuck-at faults; no silicon overhead; works with scan; can reduce number of scan circuits or vectors needed	Circuits that draw current in static state (like SRAM sense amps) must be isolated; slow (100 kHz to 1 MHz) on tester; highly pattern-dependent for signal-to-signal shorts	Some CAD tool support; many ASIC vendors have no support yet

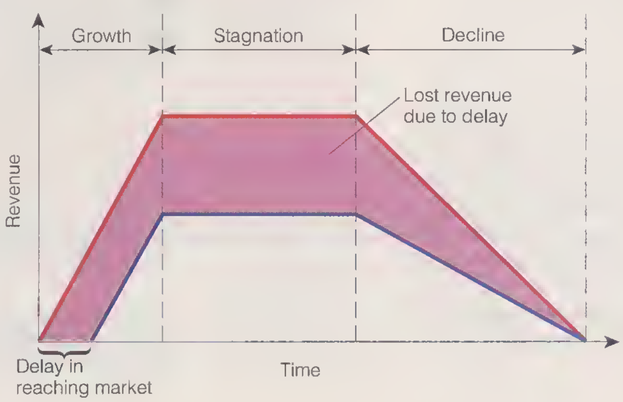
CAD = computer-aided design; SRAM = static random-access memory.

ing is not recommended for ASICs with more than 10 000 gates. If all possible faults are tried, fault simulation is computationally extravagant. A random sample of the faults can be used, but the fault coverage for a typi-

DEFINING TERMS

Automatic test pattern generator (ATPG): a software program that, given a circuit description, automatically generates a test to detect the fault types specified for that circuit.
Built-in self test (BIST): a design method that allows a device to test itself by adding logic for test signal generation and analysis of test results.
Controllability: the ability to set a node inside a device to a desired value (1 or 0) via an external pin.
Design for testability (DFT): design of a chip to enhance its controllability and observability and thereby ease test generation.
Fault coverage: the percentage of all possible device faults detected by a set of test vectors.
Fault detection: the ability to determine if a fault is present.
Fault diagnosis: the ability to locate a fault and determine its cause.
Fault simulation: the process of using software to simulate the operation of a circuit to which faults have been intentionally added so that the ability of a set of test vectors to find the faults can be determined.
Observability: the ability to determine the value (1 or 0) at a circuit node inside a device using its external pins.
Scan design: a design method in which special circuits are used to convert a sequential circuit to a combinational one to ease test generation.
Stuck-at fault: a physical defect that causes a node in a circuit to remain at a fixed logic value (usually 1 or 0).





[1] The amount of time spent developing an ASIC test depends on how well its internal elements can be controlled and observed (top). If test development delays a product's introduction (bottom), revenue (shaded area) and profits will drop sharply.

cal test developed in this manner is only 60–75 percent, which results in a defect rate of 1–2 percent in the parts that pass the tests. In practice, it can take one-half to two engineer-years to reach acceptable levels of fault coverage, which reduces or eliminates an ASIC's rapid turnaround.

Another hurdle is moving test vectors from the simulation environment to the tester. A set of vectors that runs fine in a simulator often cannot be accurately transferred to the tester because the tester's vector storage/timing capability is limited. So engineers must either rewrite the test vectors or live with far less fault coverage.

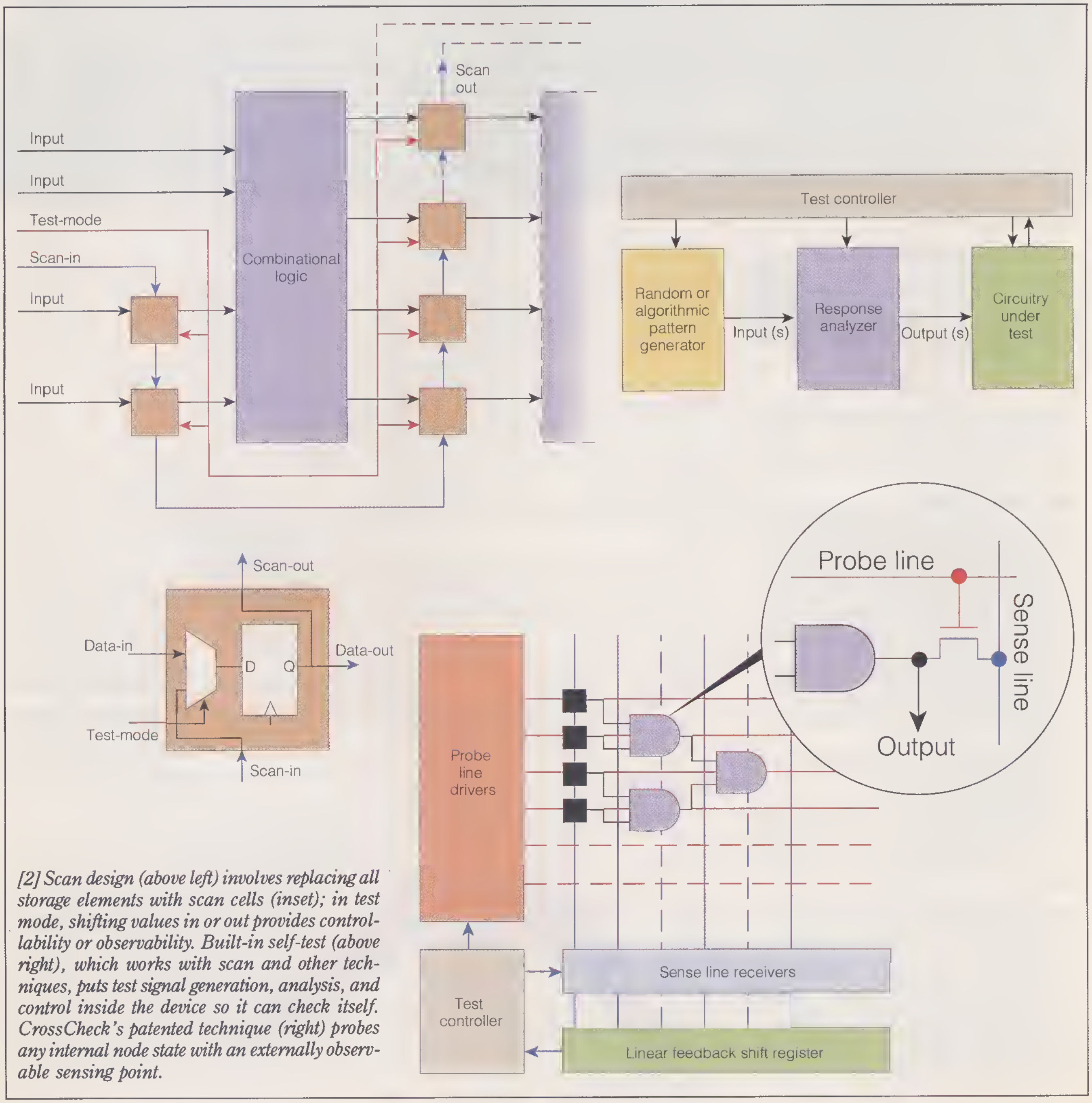
TEST RULES. As designs grew more complex, designers familiar with testing problems began to adopt nonbehavioral tests and *ad hoc* testability techniques. For a nonbehavioral test to succeed, each element of the ASIC must exhibit controllability and observability. That is, it must be possible to control an element's state through its inputs and observe its operation at its output.

Ad hoc testability techniques increase these properties by imposing design rules tailored to the circuit at hand. For example, rules may insist that designers provide a means of initializing all storage elements and breaking all feedback loops to permit control of an element's state. They must also partition large blocks into smaller, simple-to-test blocks and add test points for accessing internal nodes directly.

Although generating a test may be easier when *ad hoc* testability is added (because of partitioning), the types of *ad hoc* methods and how they are applied are different in each case. The result is custom design and test engineering efforts, and such efforts are in direct opposition to the premise for choosing an ASIC solution.

ASIC TEST TODAY. To overcome the limitations of these test approaches, high-productivity testing methodologies were developed. For ASICs, three methods offer hope of cost-effectively ensuring quality: scan (in a variety of forms), built-in self-test, and massive observability [Fig. 2].

A workhorse in easing the ASIC test problem is a set of techniques called scan design. While scan test has many variants, their common goal is to achieve full controllability and observability in the ASIC by design.



[2] Scan design (above left) involves replacing all storage elements with scan cells (inset); in test mode, shifting values in or out provides controllability or observability. Built-in self-test (above right), which works with scan and other techniques, puts test signal generation, analysis, and control inside the device so it can check itself. CrossCheck's patented technique (right) probes any internal node state with an externally observable sensing point.

To this end, the circuit's storage elements, flip-flops, and latches are replaced with elements that have been modified to operate in two modes: normal and test.

In normal mode, the scan storage elements perform the same tasks as the standard elements they replace. In test mode, however, the storage elements link to form a shift register, often referred to as a scan chain. The shift register allows an arbitrary value to be placed into the ASIC's storage element, and permits the data in the storage element to be shifted out and examined. These elements can then behave as inputs to and outputs of the devices in the circuit to which they connect.

Such a transformation makes a complex sequential circuit break down into a combinational circuit that is much easier to test. To apply a vector, the ASIC is put into test mode and a pattern that initializes the internal state of the chip is shifted into the scan chain via a scan-in pin. The ASIC is then put into normal mode, its input pins are stimulated with a test vector, and a single clock pulse is applied.

After the vector is clocked through the combinational logic and the result captured by the scan elements, the ASIC is put back into test mode so the results can be shifted out via the scan-out pin. The tester can then compare the actual result to the expected (good) result. (In practice, the shifting in of a new vector and the shifting out of the previous response are overlapped to save time.)

All aspects of the scan test method—conversion of storage elements, generation of test vectors, and the application of the vectors—are mechanical. For this reason, scan has been automated without much difficulty: in one day, the latest generation of test-synthesis tools can generate and verify test vectors for a 50 000-gate ASIC that give 95 percent stuck-at fault coverage.

However, tester hardware must be able to handle large data requirements. A 50 000-gate ASIC may well require more than 3000 scan elements and 2000 test vectors, which translates into more than 6 million cycles that the tester must apply to the ASIC.

If the tester is not properly equipped for scan testing, a test of this size may take an uneconomical amount of time owing to frequent pauses to reload the tester's vector storage memory. To free up such a tester, an ASIC vendor may limit the number of scan test cycles allowed, giving less fault coverage than desired.

Despite the problems and limitations of scan testing, the overwhelming advantages of having high-productivity design tools guaranteed to produce a testable ASIC make scan extremely powerful. Also, design tools are emerging that overcome scan's limitations and problems. For these reasons, scan has emerged as the dominant design-for-testability (DFT) technique for ASICs. But it must be used with care; many designers have been "burned" by poor implementation of the methodology.

Since scan can limit circuit performance, and since there are now test-generation tools that handle some simple sequential circuits, designers are turning to partial-scan techniques, using tools that combine scan-element insertion and automatic test-pattern generation (ATPG) in a tight, iterative loop.

Starting with some or no elements in a design's scan chain, ATPG is run. If the test generator has trouble in an area of the design, scan elements are inserted into the chain to ease test generation. This process is repeated until fault coverage is satisfactory or the constraints are exhausted.

> The correct approach may not be a single testing methodology, but a combination of two or more

KNOW THYSELF. Built-in self-test (BIST) lets the ASIC test itself. This is achieved by designing a stimulus generator and a response analyzer into the ASIC. During testing, the stimulus generator applies the patterns to the device under test and the response analyzer gathers results in the form of a long binary string and compresses it, for instance, into a single hexadecimal word, called a signature. This signature is compared to a signature for a good circuit; if the signatures match, the device is good.

In practice, BIST is used on a portion of a design rather than for a whole design. For instance, it is used to test large memory structures (RAMs and ROMs) inside the ASIC because they are very regular and their tests are algorithmic, that is, the tests can be reduced to a few program lines that are easily stored and run. ASIC vendors are now beginning to offer BIST capability in support of such testing.

To test combinational logic, BIST usually builds upon scan design, attaching the stimulus generator to the scan-in line and connecting the response analyzer to the scan-out line. Since combinational logic lacks the regular structure of, say, memory, the stimulus generator is usually a form of pseudorandom pattern generator.

For nonregular structures, a solid analysis effort is needed to calculate a good signature, and designers must make sure it is stable and repeatable; having two good parts with different signatures, or a good and bad part with the same signature, is useless.

A PANORAMIC VIEW. Since the purpose of a test is to excite a fault and propagate its effect to an observable port, ensuring that any fault can be observed—a characteristic called massive observability—solves half the test problem. Currently, two methods for achieving massive observability—CrossCheck and quiescent current, or I_{DDQ}, testing—are available to the ASIC world.

CrossCheck, which was developed and patented by CrossCheck Technology Inc., San Jose, Calif., adds a grid of built-in test points to an ASIC's base array. When the design is placed and routed, a test point is automatically connected to every gate's output. Each test point is a simple transistor that allows the value of the gate's output to be transferred to a sense line when a corresponding probe line is activated. The value on the sense line is compared to an expected value or used to compute a signature. For each vector in a test, all probe lines that have gates on them must be activated before the next pattern is applied.

The quiescent current test method exploits two properties of the static CMOS gates found in most ASIC cell libraries: a gate draws very little current (approximately 1 pA or less) when not switching (quiescent); and most defects cause a large current to flow in the quiescent state.

For quiescent current testing, the power-ground network that interconnects every gate acts as a global output bus. To test a device, a vector or vector sequence is applied and the ASIC is allowed to settle into the quiescent state. The power-supply current is then measured and, if a defect is present, a large current (typically over 20–100 μA, depending on the number of gates) is detected. To find all gate-level stuck-at faults, the test vectors need only produce both logic states at every node in the circuit. Meeting this simple criterion easily provides high fault coverage.

TO PROBE FURTHER. The latest developments in testing are presented every year at the IEEE-sponsored International Test Conference; in 1992, the conference will be held at the Baltimore Convention Center, Sept. 20–24. For information, contact the International Test Conference, 514 E. Pleasant Valley Blvd., Suite 3, Altoona, Pa. 16602; 814-941-4666.

Among the numerous books published in the field of testing, the most recent and complete is *Digital Systems Testing and Testable Design* by M. Abramovici, M. Breuer, and A. Friedman (W.H. Freeman, New York, 1990), which covers many of the issues involved in design for testability and automatic test pattern generation. An excellent glossary of test and design-for-testability terminology can be found in *Testability: Test and Emulation Primer* (Texas Instruments Inc. publication SSYA002).

ABOUT THE AUTHOR. Marc E. Levitt (M), a member of the technical staff of Sun Microsystems Corp., Mountain View, Calif., is currently involved in the design and test of ASICs, Sparc processors, and computer systems.

CCDing in the dark

This designer found that analog charge-coupled device circuitry clearly outperformed digital logic in his night vision system

It is no secret that the success of the United Nations forces in the Persian Gulf War was due in part to excellent night vision equipment. Although the press coverage at the time hinted at state-of-the-art technology, most of the infrared (IR) imaging gear deployed against Iraq had been developed (but not used) for night operations in Vietnam.

Effective as they were, those systems have several disadvantages. Today a new generation of thermal imaging sensors, designed to overcome those drawbacks, is just going into production. The new sensors exploit charge-coupled device (CCD) technology in their custom video-processing ICs to reduce the cost, size, and power requirements of the newer systems while simultaneously increasing their sensitivity and reliability [Fig. 1].

The early sensors were elegant designs for their time. They used an electro-optical multiplexer (E-O Mux) to multiplex and reformat the IR image data gathered by a linear array of IR detectors for display on a TV monitor [''The end of night,'' p. 32]. The new systems replace the electromechanical complexities of the E-O Mux with solid-state circuitry but retain linear detector arrays, though systems based on focal-plane detector arrays are under development ['Blazing ahead,'' p. 34].

DIGITAL PROS AND CONS. Obviously enough, the first efforts to develop a solid-state replacement for the E-O Mux centered on digitizing the IR information and then processing it with digital ICs. All the signal processing could be done in the electronic domain, with no need to sense light intensities of a LED array, as in the E-O Mux.

Eliminating the optical interface between the LED array and the video camera could improve a sensor's vertical and horizontal resolution, as measured by its modulation transfer function (MTF). Perhaps more importantly, an all-digital system would eliminate the video camera itself—the main source of the E-O Mux's size, weight, and reliability problems. Digital IC signal processing, in other words, could improve many aspects of an IR imaging system.

William P. McCracken Texas Instruments Inc.

Unfortunately, in addition to its undeniable advantages, the digital scan converter, at least as it could be implemented in the late '70s and early '80s, also had numerous disadvantages. It required a large number of devices to digitize each detector channel and store the individual pixels for reformatting. Consequently, it required a large number of circuit boards and lots of electrical power. To fit the circuitry into the desired system package, surface-mounted printed-circuit boards and components meeting military specifications had to be used, driving up the system cost.

For those reasons, in October 1985 the Image Sensor Technology Center at Texas Instruments (TI) Inc. with internal funding from the Defense Systems and Electronics Group, began a project to apply custom analog CCD technology to IR signal processing. Like the all-digital approach, the CCD implementation would take discrete time samples of the IR signal, but instead of digitizing the samples, it would store and manipulate them in analog form to accomplish the signal processor's goals. Benefits of the CCD approach included lower power dissipation, fewer ICs, and the ability to use pinned-package parts and relatively inexpensive through-hole circuit boards while achieving the desired system volume.

> Thermal imagers tougher than those of the Gulf War also let tank crews spot targets at longer range

THE CCD APPROACH. The initial design effort was aimed at developing a component for multiplexing and reformatting an IR detector's signals into a TV-compatible format. The result was the CCDR1, a 20-channel CCD reformatter that combined the functions of a multiplexer and a reformatter [Fig. 2]. Key to its operation were its two independent memories, one of which could be receiving parallel data from the IR detector while the other was reading out previously acquired data in serial form.

Two types of IR systems were designed to incorporate the CCDR1. The first is a small, inexpensive, medium-performance, serially scanned system commonly referred to as the Serial Technology Advancement-Forward Looking Infrared (STA-FLIR) system. Serially scanned systems use a fairly small detector (fewer than 20 IR-sensing elements), which greatly reduces overall system size and cost. On the other hand, such a system cannot cover the field of view in a single sweep. Instead, it performs multiple sweeps, which must be at a higher horizontal scan rate than those of a parallel system in order to cover the field of view in the same length of time. Since the system has less time to accumulate charge from each pixel at the higher scanning rate, the signal-to-noise ratio (SNR) is reduced and overall system sensitivity goes down. However, techniques such as increasing the detector's bias current to enhance sensitivity and incorporating time-delay-and-integrate (TDI) processing of multiple detector elements (offset horizontally at the focal-plane) can be implemented for a small detector to improve the sensor's SNR.

Serially scanned systems are very compact and can be easily packaged for various applications, which could include navigation, surveillance, search and rescue, and remotely piloted vehicles. In extensive field-testing

Defining terms

Charge-coupled device (CCD): a charge-transfer device that stores electric charges of various amplitudes in potential wells and transfers those charges as packets by translating the positions of the potential wells.

Minimum resolvable temperature difference (MRTD): the smallest amount by which a blackbody illuminating source must be raised above the ambient temperature so that a human being can just discern the four bars of a standard test pattern when viewing the target through the thermal sensor under test.

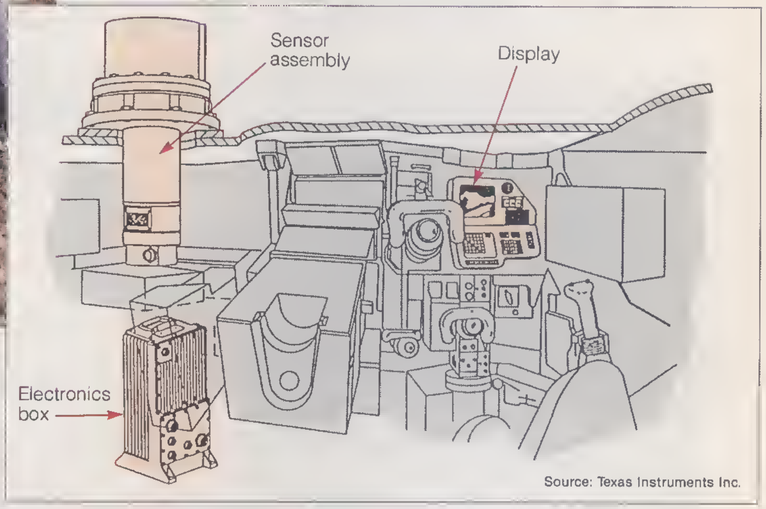
Modulation transfer function (MTF): the Fourier transform of the point spread function, which describes the system's imaging resolution and the contrast reduction of a sinusoidal brightness pattern over a range of spatial frequencies.

Noise-equivalent temperature difference (NETD): the temperature difference between two adjacent targets required to just equal the noise amplitude of the sensor's signal.

0018-9235/92/$3.00©1992 IEEE

General Dynamics Corp.

Texas Instruments Inc.



[1] The CCD-based infrared viewing system mounted on the top right side of the turret of the M-1A1 tank (above) is more sensitive and more rugged than its electromechanical predecessors. For easy maintenance, the system is contained in two line-replaceable units—a sensor and an electronics box (top right, at left and right, respectively). The display is on the tank commander's console (bottom right).

and demonstrations this system has been used as a nighttime driver's aid, a remote surveillance sensor, and an airborne navigation FLIR.

The second IR sensor built around the CCDR1 is the Photo Conductive–Advanced Scanning Array Module (PC-ASAM). This sensor is a relatively low-cost, medium-sized, high-performance, parallel-scanned system ["The end of night," p. 32]. It has been extensively used for data collection to support several design and test efforts.

In terms of IR sensor performance, both systems exhibit respectable measurements for noise-equivalent temperature detected (NETD) and minimum resolvable temperature detected (MRTD) [Table 1]. For both parameters, the lower the number (given similar system characteristics), the greater the sensitivity to fractional temperature differences. In the case of MRTD, note that the PC-ASAM is not less sensitive than the STA-FLIR (as indicated by the NETD measurement); the higher MRTD value in the table is a consequence of the higher spatial frequency modulation of the target: 5.0 vs. 0.6 cycle per milliradian.

THE SECOND GENERATION. The successful development of CCDR1 and its favorable reception encouraged TI to develop an improved version. It was determined that the

1. Several infrared imaging systems compared

	Performance		System characteristics		
				Optics	
System	NETD, °C	MRTD, °C @ target, cycles/mrad	Horizontal resolution,[a] cycles/mrad	Relative aperture	Area, cm²
STA-FLIR	0.16	0.19 @ 0.6	0.60	2.00	7.29
PC-ASAM	0.15	0.28 @ 5.0	5.00	2.35	366.13
TTS	0.11	0.17 @ 3.0 0.25 @ 4.0	2.67	2.08	133.35
CITV	0.09	0.10 @ 3.0 0.15 @ 4.0 0.28 @ 5.0	2.67	2.13	126.71

a Based on a standard 50.8-μm (2.0-mil) detector width.
NETD = noise-equivalent temperature detected.
MRTD = minimum resolvable temperature detected.
STA-FLIR = serial technology advancement–forward-looking infrared.
PC-ASAM = photoconductive–advanced scanning-array modules.
TTS = tank thermal sight.
CITV = commander's independent thermal viewer.

2. Reliability predictions of video sensor electronics

System[a]	Mean time between failures, hours	Improvement over common-module sensor, %	Evaluation ambient temperature, °C	Mission environment
Common module	864	—	55	Airborne
PC-ASAM[b]	1228	42	55	Airborne
Hypothetical system with CITV[b] electronics	2314	168	60	Ground-based

a 180-channel systems.
b See Table 1.

CCDR1's noise would be reduced significantly if input and output operations were not simultaneous. One way to do that, limiting the device to a single memory section, would also allow the memory to expand from 20 to 60 channels.

The enlarged memory would reduce the system board count, cutting the sensor's cost, size, and power consumption. Moreover, minimizing the total number of interconnections required between the numerous amplified detector signals and the reformatting devices would also be advantageous for production costs, sensor reliability, and packaging flexibility. Hence, multiplexing the amplified detector signals before the CCD reformatting operation was desirable. Taken together, those considerations suggested that the second-generation device be a CCD signal-processing chip set consisting of a 60:1 channel multiplexer (CCDM) and a 60-channel reformatter (CCDR2).

Unlike most multiplexers, the CCDM can suspend output operations when sampling inputs and transferring charge, thus protecting acquired data samples from corruption by clock noise. It can implement a four-stage finite-impulse-response (FIR) filter in its input structure. That helps to limit the bandwidth of the incoming signals, attenuating the aliasing noise power associated with sampled-data systems. The FIR filter is implemented by summing four time-delayed input samples from each channel to form a pixel sample within one of the two summing wells of the input structure [Fig. 3]. The sequence is repeated to form a second pixel in the second summing well. The pixel samples are then transferred from the summing well into the multiplexer's pixel buffer.

The multiplexer samples all 60 of its input channels simultaneously to ensure that rapidly changing scenes are not distorted by electronic timing artifacts. Also, to ease the performance requirements on the CCDR2, the CCDM contains a small (four-pixel) buffer for each channel, which reduces the required input operating speed of the CCDR2 by a factor of four. In short, the CCDM combines a flexible 60-channel multiplexing function with additional signal-processing capabilities. And it packages all that capability in a single 2.8-by-2.8-cm, 74-pin, pin-grid array.

From the multiplexer, the serial output signal is fed to the CCDR2 reformatter [Fig. 4], where the pixel samples are demultiplexed and stored in the 60-channel memory. Because the CCDR2 has only one memory, it must be used in pairs to handle

The end of night

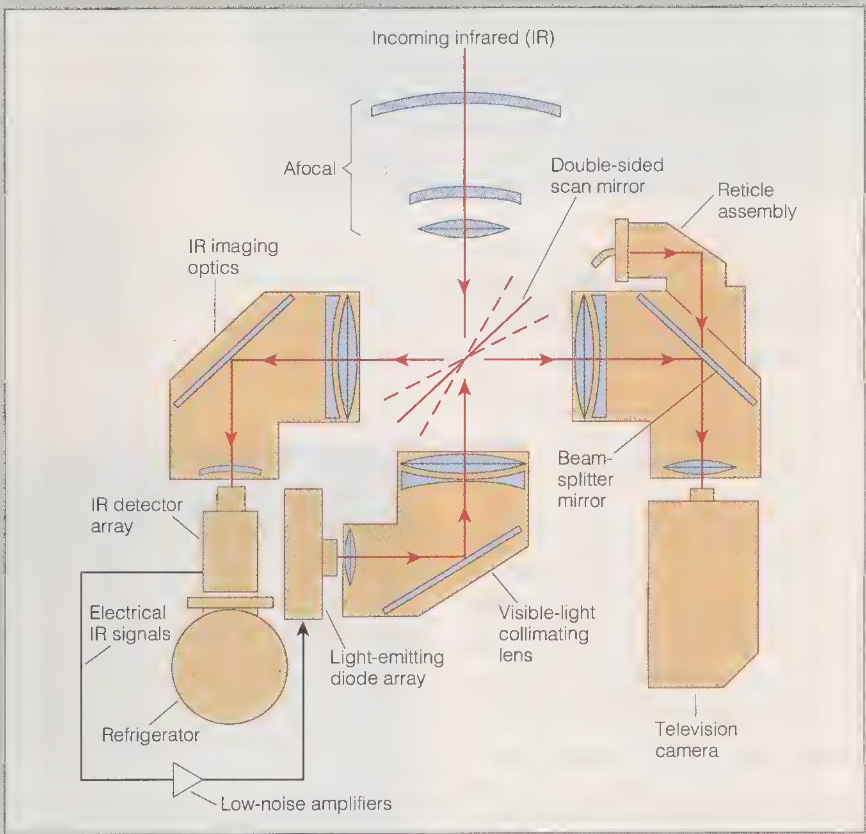
An infrared imaging system helps us to see at night—even a moonless, starless night. It does so by converting the thermal energy in the darkness ahead into a visible image. The earliest such systems, known as image converters, required a transmitter to illuminate the scene with invisible infrared radiation; and German tanks on the Eastern front used such "active" sensors with favorable results in 1944. But all modern systems are "passive" in that they form visible images from naturally occurring IR energy. Indeed, were they to include illuminating sources, they would become excellent targets, readily detectable by the crudest of sensors.

The infrared region covers an enormous part of the electromagnetic spectrum—from about 0.75 to 1000 μm. But only a small part of that range is used in thermal imaging sensors: the 3–5- and 8–12-μm bands, where atmospheric attenuation is minimal. Energy in those bands may be radiated by the target, reflected from it, or both. A human being or an automobile can be "seen" by its own IR radiation, which is proportional to its surface temperature. Clearly, many variables come into play in forming an infrared image: temperature, surface finish, surroundings, atmospheric conditions, and so on.

In just about all modern thermal imaging systems, information about the IR energy levels of a scene is acquired by horizontally scanning a portion of the scene's IR radiation across a column of IR detectors. The vertical alignment of multiple detectors improves the IR system's vertical resolution and minimizes the required horizontal scan rate. The scanning of the scene produces a set of parallel electric signals—one from each detector—thus this type of sensor is known as a parallel-scanned system.

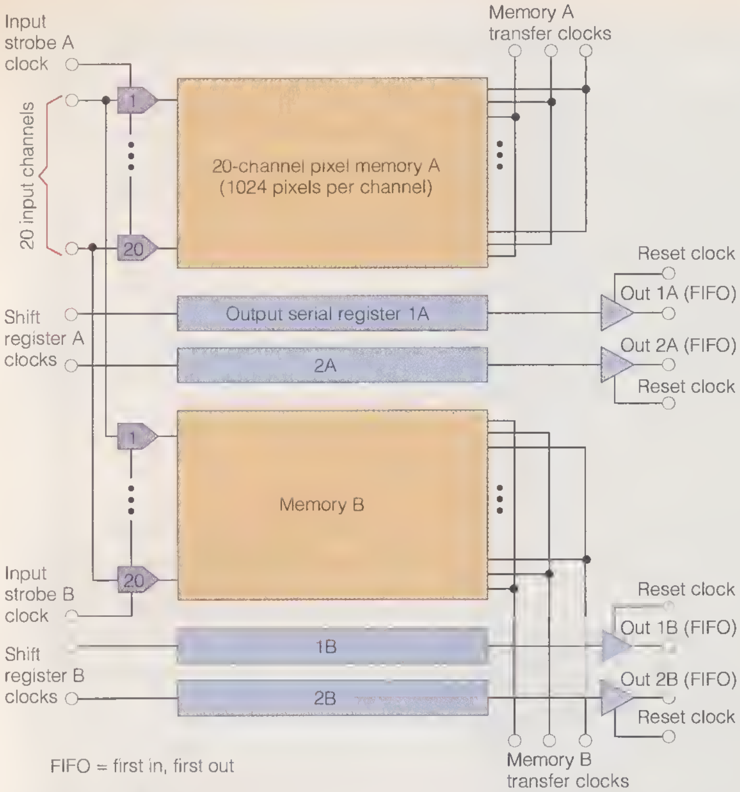
Multiplexing the parallel IR signals into a serial data stream is necessary to generate a serially formatted input signal for television monitors. The TV then displays the IR scene in the visible region of the spectrum for interpretation by the operator.

Typically, a scene is scanned across the detector array by a moving mirror. A 60-Hz scan rate is the norm, to synchronize with the TV field rate. Each scan produces an IR signal about 10 ms in duration. Since a single TV scan displays information for only 52 μs, the IR signals must be compressed, or reformatted, for display on a TV monitor. The two essentials for processing IR image data into a form suitable for display, therefore, are multiplexing and reformatting.

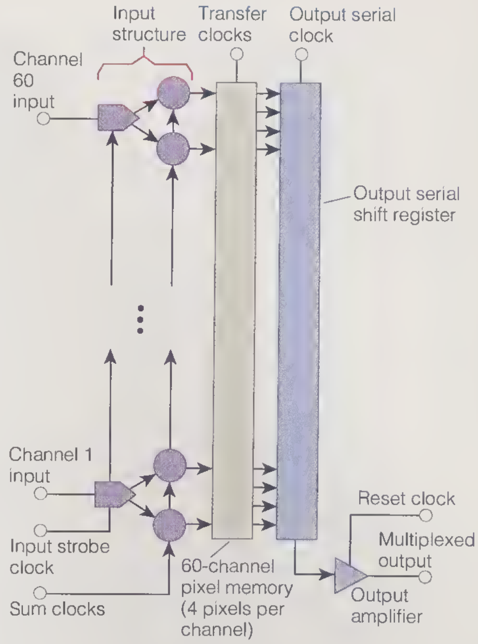


The first thermal imaging sensors to reach volume production, called common-module systems because they were built from a common set of components, came out in 1972. They used an elegant electromechanical device called an electro-optical multiplexer (E-O Mux) to simultaneously multiplex and reformat their data [see figure]. The heart of the E-O Mux is a linear array of light-emitting diodes (LEDs) that is geometrically equivalent to the IR detector array.

The electric signal from each detector element is amplified and used to drive the corresponding element in the LED array. As the IR radiation is moved across the detector by the scanning mirror, the backside of the same mirror simultaneously scans the light emitted from the LED array across the front of the video camera. The light intensity of the LEDs varies with IR changes in the scene, and these variations are observed by the camera, which produces a multiplexed and reformatted output signal to drive a TV monitor. —*W.P.M*



[2] The first-generation CCDR1 reformatter samples 20 input channels and transfers the pixel samples into one of two pixel memories. Information is then serially transferred out of the device from one memory while fresh data is being loaded into the other.



[3] Half of the second-generation chip set, the CCD multiplexer, adds sequential (time-delayed) charges in its summing wells (circles), effectively implementing an anti-aliasing filter.

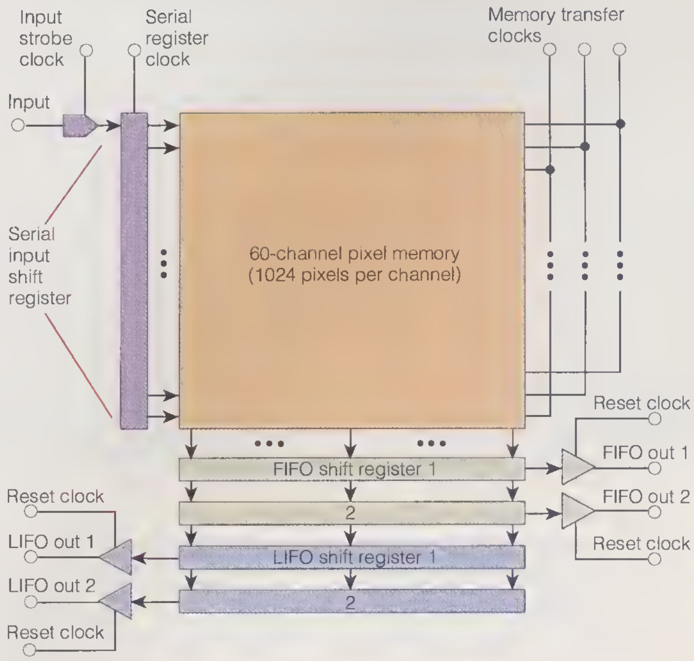
a complete TV frame's image. Only four boards—each with a pair of CCDR2s—are required for a 240-channel parallel-scanned system, a substantial reduction in electronics compared with the 12 CCDR1 boards needed for an equivalent system.

An additional feature of the CCDR2 device is its ability to output stored information as either a first-in, first-out (FIFO) or last-in, first-out (LIFO) shift register. That adds flexibility to the electronics, allowing for different system configurations as well as operational modes. The CCDR2 package is a standard 28-pin, 600-mil-wide, dual in-line device.

Besides being small and using little power, these CCD signal processors require fewer support components than most CCDs. The savings are due to a patented scheme for using only one clock to transport charge inside the device. Without that scheme, which TI calls Virtual Phase Technology, two or three clocks would be needed.

NOISE HURTS. A large SNR is one of the most desirable attributes for the video electronics in a thermal imaging system. The larger the SNR, the less likely is noise to mask a small temperature difference within a scene. Ideally, every IR system would exhibit detector-limited performance—a condition in which the only perceptible noise components are those inherent in the IR detector's semiconductor structure and the photon emissions of the scene's background.

The measured pixel SNRs of the CCDM and the CCDR2 come very close to their modeled values. The CCDM's measured SNR was 59.7 dB vs. a theoretical value of 61.0 dB; the CCDR2's measured SNR was 55.9 dB vs. a modeled 59.7 dB.



[4] The second half of the chip set, the CCDR2 reformatter, takes data from a CCD multiplexer into its serial input register, stores it in pixel memory, and then clocks it out via one of its output registers.

The dynamic range (DNR) of an IR system is normally defined as the SNR at the sensor's minimum gain. The larger the DNR, the wider the range of IR energy levels that can be displayed, and hence the more accurate the rendering of the scene.

HUNTING AND KILLING. The first major production application of the second-generation CCD chip set is in a new infrared

Blazing ahead

Whether supported by electro-optical multiplexing or more modern charge-coupled device (CCD) circuitry, just about all current infrared imaging systems are based on linear arrays of photodetectors. That situation should last until the late '90s, at which time new technology, now under development, can be expected to take over.

Expanding military and commercial needs for night vision are driving industrial, university, and government laboratories to provide sensors with more resolution, larger fields of view, and better sensitivity than common-module systems can deliver. Commercial applications are particularly demanding in that they require very low cost, low maintenance, and high reliability in extreme environments—in automobiles, for example.

To satisfy the anticipated demand, engineers have been moving in the obvious direction: building two-dimensional detector arrays with thousands of elements in the focal plane. Compared with today's common-module linear arrays, which have no more than 180 detector elements, 2-D arrays produce better resolution and a larger field of view. Because the 2-D device is a "staring" array—one that does not have to be scanned—it also increases the system signal-to-noise ratio. That improvement, which is proportional to the square root of the array size, comes from the decrease in noise bandwidth required by the staring array.

The most direct approach for fabricating large focal planes—making CCD arrays from narrow-bandgap semiconductors like mercury cadmium telluride (HgCdTe)—is not feasible because of the high intensity of infrared radiation coming from the ambient. That radiation would cause the CCD wells to saturate after only 20 μs of integration. The infrared equivalent to the silicon CCD camera is possible, but it will work for just a few applications.

Instead, the advanced focal planes under development today are hybrid structures. Most are HgCdTe photodiode arrays mated to silicon IC processors containing a matching array of amplifiers. The IC also performs correlated double sampling (processor noise reduction to less than 20 μV) and multiplexing to a few output buffers. The amplifiers are often capacitive-feedback transimpedance buffers capable of integration to the full frame rate of 30 Hz.

HgCdTe diode arrays up to 512 elements square have been developed for the 3–5-μm infrared region; for 10-μm wavelengths, the state of the art is currently 128 elements on a side. (The difference is due to the higher infrared photon flux encountered at 10 μm and the consequent need to handle more charge.) The diode arrays are made in a chip of HgCdTe and are pressed onto the silicon IC, connecting the bump electrodes of the detector elements to corresponding bumps on the IC. Another approach is to glue the HgCdTe chip to the IC, thin the detector material to less than 10 μm, form the diodes, and then fabricate a thin-film interconnect for each diode through a hole in the HgCdTe.

When the 10-μm arrays get to the 512-by-512 size, they will be suitable for most military applications: night vision, target recognition, nighttime terrain following, and missile seekers. Of course, like current systems, they will have to be cooled to less than 80 K for optimum performance. While the necessary cooling modules have become more reliable, they still consume a significant amount of power, make noise, take up room, and increase costs.

For those reasons, many commercial applications—including night vision aids for vehicles, ships, and aircraft; medical diagnostics; law enforcement; and manufacturing control—which do not require the sensitivity of military equipment, will probably use uncooled focal-plane arrays of IR detectors other than HgCdTe mated to silicon ICs. The detector elements will be either semiconductor microbolometers or ferroelectric photocapacitors. Arrays of those types with over 40 000 elements are currently under development. Eliminating the scanning and cooling modules will make those commercial sensors both highly reliable and relatively inexpensive. Their sensitivity will be similar to that of today's common-module systems—about 0.10 °C.

Peering into the next century, it seems likely that new semiconductor materials will be available to make possible monolithic focal-plane arrays—integrated circuits that can "see" infrared. On-chip circuitry will automatically correct the output signals for internal offsets. Moreover, high-density digital logic will be available for processing the output and interpreting it in a variety of ways. In effect, human ingenuity will have extended human vision deep into the infrared region of the spectrum.

—Seb Borrello, TI Fellow, Texas Instruments Inc.

system designed to give an M-1A1 tank commander an independent view of the battleground [Fig. 1]. Called the Commander's Independent Thermal Viewer (CITV), the new system supplements the gunner's thermal viewer, enabling tank crews to hunt and kill simultaneously.

Early in the design of the CITV, an evaluation of the proposed CCD video chain was undertaken to verify full performance compliance. That modeling and measurement effort concluded that the CCD approach would surpass the CITV system's requirements. The measured DNR of the entire video electronics chain was 42 dB, compared with a calculated value of 49 dB.

By way of comparison, the Tank Thermal Sight (TTS) system has been manufactured for 10 years and has achieved a respectable field reputation. It makes a good standard of comparison, having an identical 120-channel IR detector to the CITV sensor's and very similar optics [Table 1]. The CITV's more sensitive MRTD measurements will increase the range for target identification, which ultimately improves the tank's battlefield situation.

In addition to lower noise, CCD video chain designs also deliver more reliability than earlier technologies [Table 2]. Reliability predictions for the common-module sensor and the 180-channel PC-ASAM (containing the CCDR1) were conducted according to military handbook directions with an ambient temperature of 55 °C.

An equivalent, hypothetical 180-channel sensor utilizing the CITV video electronics (incorporating the second-generation CCD chip set) exhibited even more improvement. The reliability predictions for the CITV are based on an ambient temperature of 60 °C.

All the custom CCD devices performed well in tests over the military ambient temperature range of –55 °C to +125 °C. They also did well in radiation-hardness testing, performing acceptably after the required exposure to both gamma and neutron radiation.

The CITV program has completed its baseline design and delivery of 18 prototype systems. In February 1991, a contract was awarded for the first year of volume production.

Other applications for the CCD IR imaging technology include an airborne system, built around the second-generation chip set, of which eight prototypes have been ordered under a full-scale development contract.

In addition, a third program, based on the first-generation CCDR1 device, is developing a spinoff of the STA-FLIR sensor for a variety of military and civilian vehicular and airborne applications. Prototypes of this system, which has a potential market of thousands of units, have been built and field testing has been completed. The first production contract for over 600 systems was awarded in September 1991.

Clearly, the analog CCD approach for processing IR signals has proved its value in a variety of applications. It allowed us to develop a high-quality thermal imaging system that both increases system performance and reduces production cost.

TO PROBE FURTHER. Two highly regarded books on infrared technology are *Thermal Imaging Systems* by J.M. Lloyd (Plenum Press, New York, 1975) and *Infrared Handbook* by W.L. Wolfe and G.T. Zissis (Infrared Information Analysis Center, Environmental Research Institute of Michigan, Ann Arbor, 1978), which was prepared for the Office of Naval Research, Department of the Navy. A superb reference for CCD technology is *Charge Transfer Devices* by C.H Sequin and M.F. Tompsett (Academic Press, 1975). For a deeper look at the historical development and application of solid-state imaging along with the physics of photosensors, see *Solid State Imaging* by Paul Jespers, Fernand Van De Wiele, and Marvin White (Noordhoff, Leyden, the Netherlands, 1976).

ACKNOWLEDGMENTS. The author would like to thank Neal Cooper, Chester Murdock, Andi Hemann, and Keith Donovan for their support in writing this article.

ABOUT THE AUTHOR. William P. McCracken has been involved in electronic imaging ever since he joined Texas Instruments Inc., Dallas, in 1985. Currently, he is designing advanced video cameras and supporting the development of new image sensors. In previous assignments, he designed custom CCD image processors for the M-1A1's CITV system and airborne prototype sensors. ◆

NOTICE TO NATURALIZED CITIZENS FROM, OR WHO HAVE RESIDED FOR A SIGNIFICANT PERIOD OF TIME IN, THE FOLLOWING COUNTRIES:

Afghanistan, Albania, Angola, East Berlin, Bulgaria, Cambodia (Kampuchea), Cuba, Czechoslovakia, Estonia, Ethiopia, German Democratic Republic (East Germany), Hungarian People's Republic (Hungary), Iran, Iraq, Democratic People's Republic of Korea (North Korea), Laos, Latvia, Libyan Arab Republic, Mongolian People's Republic (Outer Mongolia), Nicaragua, People's Republic of China, Poland, Rumania, Southern Yemen, Syria, Union of Soviet Socialist Republics, Democratic Republic of Vietnam (North Vietnam), South Vietnam, Yugoslavia, the Kurile Islands and South Sakhalin (Karafuto).

YOU MAY HAVE BEEN THE VICTIM OF UNCONSTITUTIONAL DISCRIMINATION BASED ON YOUR NATIONAL ORIGIN

If you are a naturalized United States citizen and your country of origin is included above, or you resided in one of these countries for a significant period of your life, the Department of Defense (DoD) or a DoD contractor may have unlawfully denied you a security clearance or employment, promotion, fellowship or scholarship that required a security clearance, or asked you to apply for a Limited Access Authorization, as a result of DoD's enforcement of a regulation which denied security clearances to newly naturalized United States citizens from these countries or who resided in these countries for a significant period.

The DoD and DoD contractors acted pursuant to a regulation that became effective on January 2, 1987. Although DoD rescinded the regulation on February 12, 1988, it may have been applied after that date. The United States District Court for the District of Columbia has declared the regulation unconstitutional and permanently enjoined the DoD from enforcing it. Huynh v. Cheney, 87-3436 TFH (D.D.C. March 14, 1991).

If you are a naturalized citizen and you believe you have been adversely affected by the enforcement of the regulation on or after January 2, 1987, you may have certain legal rights. For further information, you should contact the United States Department of Justice Office of Special Counsel for Immigration Related Unfair Employment Practices (OSC), by calling 1-800-255-7688 or (202) 653-8121; 1-800-237-2515 or (202) 296-0168 (TDD device for the hearing impaired); or by writing to OSC, P.O. Box 65490, Washington, D.C. 20035-5490. The OSC will provide information and help you process a claim free of charge. The opportunity to pursue these rights is subject to certain time limits, so if you believe the regulation was applied to you, contact the Office of Special Counsel as soon as possible.

Unclogging distributed computing

Once new software is in place, thousands of dispersed computers of various brands will be able to talk to (and understand) each other

In many of today's networks, systems from one vendor merely co-exist with those of other suppliers because they are incapable of working together. Yet users want to interconnect those diverse systems, move applications from one platform to another, and host a software environment on several systems of different sizes and capabilities. In other words, users are demanding interoperability among heterogeneous computers.

These developments bring to a head the need for an efficient, flexible, secure, yet cost-effective distributed computing environment—one in which the processing power and the data are dispersed over a network of many interconnected computers, rather than resident in one machine. In such an environment users have access to computer resources distributed throughout a local or worldwide network.

One of the most comprehensive efforts toward this goal is the Distributed Computing Environment (DCE) software, developed by the Open Software Foundation (OSF), Cambridge, Mass., an industry-supported research and development organization with more than 330 members worldwide—hardware and software vendors, end users, and research institutions.

The DCE focuses on four problems that require technical solutions: the diversity of operating environments, the (generally large) number of interconnected computers, and the need to maintain security along with the need to provide opportunities both for growth and for new network applications.

Many computer vendors, representing more than 70 percent of the market in PCs and workstations, are incorporating DCE software in their products, to let them interoperate, that is, exchange information and use it. The industry's shift from proprietary to "open" systems—machines that interoperate with systems from different vendors—has come at the behest of end users. In fields as diverse as financial services, engineering, government, telecommunications, and manufacturing, users have demanded open systems as a means of protecting their investments in hardware, software applications, and training. With DCE, users in all industries will be able to develop, deploy, and manage applications that efficiently use a network's scattered computing resources.

Douglas Hartman Open Software Foundation

OSF assembled a team of experts in distributed computing, all engineers and industry consultants, to evaluate the technologies proposed for the DCE by 32 companies and universities. Working with its membership and independent consultants, OSF selected the best of the breed, then integrated them in an environment that combines and enhances the most advanced technology available.

BEYOND LANs. The 1980s saw local-area networks installed in most engineering organizations. File sharing within an organization became common through software such as Novell Netware for MS-DOS PCs and Sun Microsystems Inc.'s Network File System (NFS) for Unix workstations. This software took advantage of the high speed and low cost of the local-area networks.

> The Distributed Computing Environment permits secure, reliable applications for multivendor networks

Sharing of data remained within the local-area network, however, in order not to exceed the capabilities of the software. Companies could not tie together organizations such as departments, divisions or branches that were geographically far apart, or that used different brands of computers. Few wide-area networks existed, and they were slow and expensive, relegated to supporting batch file transfer and electronic mail.

The 1990s are already seeing dramatic changes in the economics of connectivity. The appearance of the technology needed to interconnect local-area networks over high-speed links promises to create very large networks typically of thousands of computers. By the year 2000, 80 percent of the computers used in business, education, and research will be linked to each other by wide-area networks that approximate the speed of today's local-area networks.

Linking those organizations that need to share information and resources (like files or databases) is the prime use of interconnection technology. Cross-organizational links open up new application possibilities, allowing customers and suppliers to exchange information needed in their daily business. These links also give rise to four problems in need of software solutions.

- **Diverse operating environments.** It is fairly easy to deploy advanced networking software for common hardware and a single operating system. Examples include the Apollo Domain system from Hewlett-Packard Co., Palo Alto, Calif., and DECnet from Digital Equipment Corp., Maynard, Mass. These systems interlink organizations, provided their equipment all comes from a single vendor.

As more and more organizations are linked, however, a single-vendor environment quickly becomes an impossibility. Organizations need different brands of computing equipment to communicate. Networking services thus must handle multivendor networks.

Documents such as OSI (Open Systems Interconnect) and IEEE Posix standards define solutions to multivendor operation by formally balloting vendors and users. OSI addresses networking protocols (communications between systems), while Posix addresses the interface with application programming. These organizations seek to standardize widespread practices, rather than create new designs. Since current practice is in its early days, comprehensive standards are not expected until late this decade.

- **Networks with thousands or even millions of computers.** Software systems such as NFS and Netware accommodate networks of hundreds of systems. Larger networks will require new software. Here techniques such as hierarchical design may be used. In these, several groups of rather few processors, say 100 or so, are combined into larger entities, thereby allowing the efficient management of these larger groups.

These techniques will allow software to

scale up to very large networks. For example, an initial network of, say, 20 or so computers may grow into hundreds, even thousands of computers without the need to reinstall the networking software each time several computers are grouped together. In particular, two or more groups of systems can be tied into one larger network, and this process may be repeated. This means a company-wide network can be deployed one department at a time. These techniques, developed by university and defense researchers during the 1970s and 1980s, led to such large international networks as Internet. These networks are jointly managed by these universities, researchers, and individual companies.

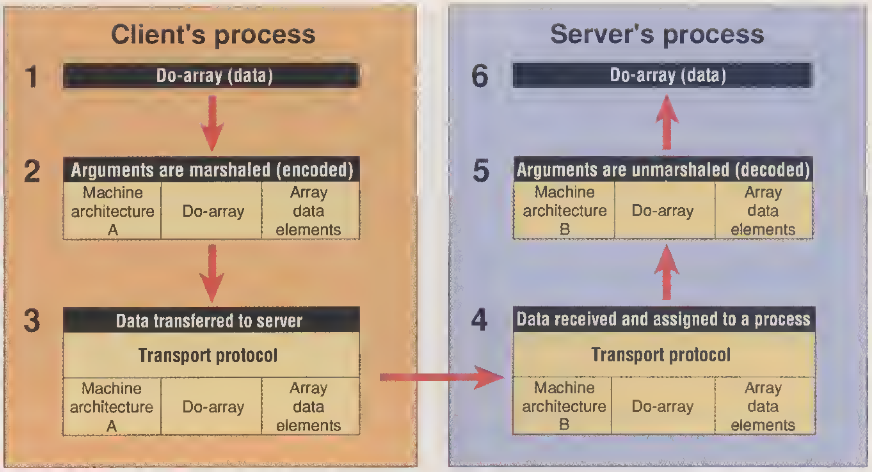
• **Maintaining security.** Before access to distributed information and resources can occur, organizations need to be able to control access to sensitive information. Most LAN software today can offer only minimal security. Encryption techniques, analogous to the use of scrambling in cable television transmissions, are one means of increasing security. They permit security over unsecured communications channels, such as cable and wireless transmission. Networking software must integrate security into basic operations.

• **Creating new network applications.** To make full use of these multi-organizational networks, users must be free to create custom solutions. These network programming techniques are like the techniques used for local-area networks, but also take care of diversity, scale, and security.

DRAWING ON OSI, POSIX. These problems loomed unanswered over the 1980s. Any solution would have to draw on the experience gained with environments that used a single operating system but be suitable for use in a multivendor environment using OSI and Posix standards.

DCE specifies programming interfaces and protocols for network computing in a form suitable for standardization. OSF also provides a reference implementation of DCE for Unix in ANSI C, which is a popular language for system programming because it allows good performance while maintaining portability. In fact, DCE is the only software platform available today to address all major issues in multi-organizational computing [see table].

Many leading computer vendors are now in the course of porting DCE software to their operating systems. Soon end users will be able to buy DCE implementations as part of the operating-system software on platforms employing Unix, VMS, MVS, MS-Windows, and other operating systems.



[1] In a typical distributed computing environment, the procedure call for the processing of an array of data, for example, may be initiated in one computer, the "client," with the actual processing executed in a "server"—another computer, sometimes with a different architecture. The process of moving this data between the client and server is transparent to the client and server applications. Here the client's application calls the do-array *procedure (step 1). A client's stub—code generated by a special compiler not shown here—marshals (encodes) the procedure's parameters (arguments) and the data associated with them in an architecture-independent way into buffers (step 2). The data in these buffers is transferred to the server by a runtime library using an appropriate transport protocol (step 3). (Such a library is a set of procedures used by a program to accomplish a standard set of operations such as network access.) The server receives the data and passes it to a designated server process (step 4). A server's stub unmarshals (decodes) the buffers (step 5) and delivers the data to the* do-array *function to be processed (step 6). The result is returned to the client's application in a similar way in the reverse direction.*

Network computing must take the physical network into account as well as the operating system. DCE software is installed on each computer in a system and accesses the network through a transport-layer interface. The typical network in the engineering community is a TCP/IP (Internet) network, but it could also be an OSI network, or an equivalent proprietary protocol.

A program that will run on multivendor networks must meet the programming requirements of the networks. They include synchronizing with programs on different systems, buffering large transfers, converting data representations (if necessary), and verifying security credentials. Such programming is tedious and subject to error when done by hand. DCE software automates the process, making it practical to create reliable, secure applications for a variety of network configurations.

For example, consider the problem of sending a large array of floating-point numbers from a VAX computer running VMS to a Sun workstation. In these two computers, the operating systems, floating-point data representations, and byte ordering when transmitting data are all different. Because the array in question is too large to be sent in a single network message, DCE software handles all the programming steps needed to send it—breaking it into pieces, transmitting the data, and converting values for the receiving computer [Fig. 1].

One illustration of how this technology is used might be a circuit-simulation package

Defining terms

Access control list (ACL): a list of users and groups of users, along with the rights granted to them.
Arguments: values passed to or from a procedure.
Buffering: gathering data into intermediate storage to improve data transfer speed.
Credentials: information regarding identity and privileges granted to a user.
Directory: list of data items and information about them used to reference the items.
Distributed computing environment (DCE): one in which processing power and data reside in many computers, rather than just one.
Encryption: encoding and decoding data via a key to restrict access to data to those who know the key.
Interoperate (noun: Interoperability): allowing multiple computers to exchange data and control information in meaningful ways.
Network Analyzer: a system used to examine or modify network information for diagnostic purposes.
Portability: the ease with which a software system or component can be transferred from one hardware or software environment to another.
Remote procedure call (RPC): a call to a procedure that resides in a computer other than the calling one.
TCP/IP: Transmission Control Protocol and Internet Protocol, the transport and network protocols used in the Internet and related networks.
Server: a computer providing service in a network.
Transport-layer interface: programming interface to layer 4 of the OSI network architecture, which is responsible for reliable end-to-end delivery of data.
X.500 directory system: a worldwide directory of information, generally used for user names and electronic mail addresses, conforming to CCITT standard X.500 and related documents.

that runs on a Unix workstation and uses sample data located on another network, as well as data found nearer home on a corporate MVS database of preferred parts (MVS is the most common operating system for IBM mainframes). Using OSF DCE software, the application can access the database and test data regardless of where the databases are located. The application can run on multiple sites, on different networks, or with different databases, all while preserving the network programming.

GLOBAL NAMING. Distributed systems use names to describe a variety of resources, such as computers, files, directories, and programs. These names must uniquely identify each resource throughout the entire distributed computing system, and remain constant when a resource moves to a different computer. The system must be able to create and manage a great many names without requiring huge look-up tables on each system.

Unique global names are easy to create if hierarchically constructed. A local resource name, such as /usr/bin/file, has one or more names prefixed to it, to indicate in which part of the system the named resource can be found. OSF DCE invents global names by prefixing a local resource name with a unique cell name. (Cells correspond to organizations, as the term is used in this article.) A cell is a collection of computers under a common administration. It might consist of 10 to 10 000 computers. A corporation or university would use one cell per organization. Large cells suit central administrations, whereas multiple cells favor local control. Cell names and locations are registered in a worldwide directory, where (generally) thousands of entries are catalogued in a distributed database maintained on assorted computers around the world. These computers are usually dedicated to support network access at corporations, universities, public telephone companies, and similar organizations. A single part of this data may require from 1 to 100 megabytes or so, depending on the quantity of information maintained at that site. The directory often takes the form of either the Internet Domain Name System, or the OSI X.500 distributed directory.

The OSF DCE uses consistent global names for the following resources: files; users; network services, such as those residing in directory and authentication servers; computers; and user-defined resources, such as printers and databases.

> By 2000, 80% of business, education, and research computers will be linked by wide-area nets as fast as today's local networks

Using the OSF DCE name syntax, a file might be named:

/. . ./mydept.mycorp.com/fs/usr/barb/file

In this example, the prefix "..." means a cell name follows, the "mydept.mycorp.com" is the cell name in Internet format, the "fs" indicates a file name, and "usr/barb/file" is the name of the file. (The cell name in X.500 format is "C=US/O=MYCORP/OU=MYDEPT", with country, organization, and organizational unit specified explicitly.)

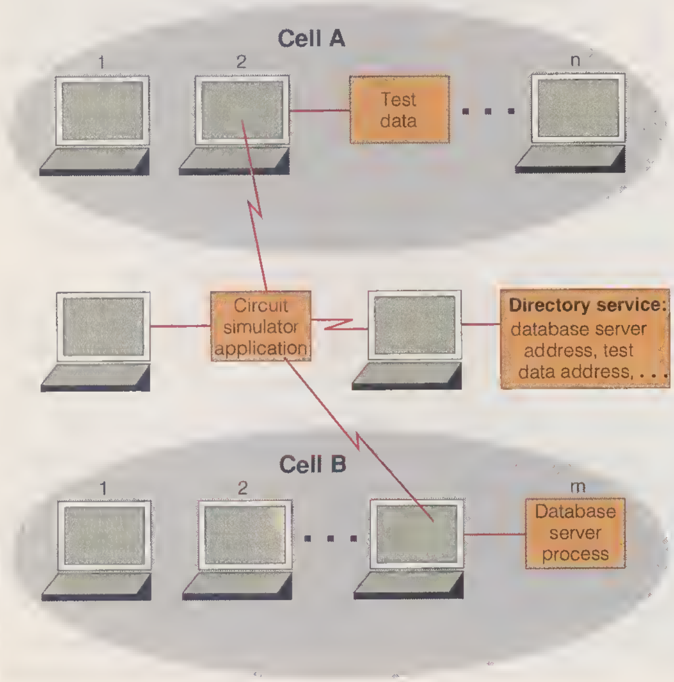
Names are stored in a cell directory. They are managed by a directory administrator, who might also administer the local-area network. They are available to users in other cells as connectivity and security policy allow. Cell directory servers cooperate to resolve name lookups that cross cells.

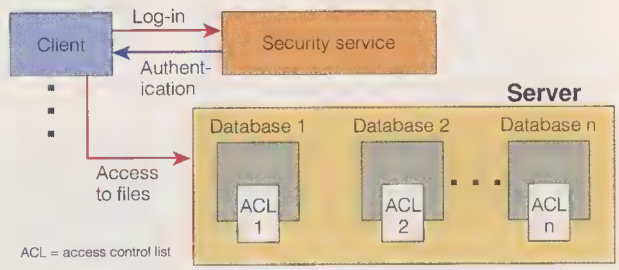
The circuit-simulation application uses the directory to find the addresses of database servers and test data. Database servers and test data can be located in different cells, even at different organizations [Fig. 2].

By using global names, the OSF DCE file system enables each user's files to form part of a worldwide file system with worldwide availability. Files can reside on dedicated file servers, as well as on a workstation. Files in all cells are combined to form the worldwide file system, as in the file name example. DCE file system data can also be accessed from file systems such as NFS.

For an example of worldwide file system use, consider the DCE software development process. DCE development took place at multiple sites, separated by thousands of kilometers, all connected by a dedicated network using an early version of the OSF DCE file system. This system allowed developers at each site to share files with other sites. For example, code drops to fix bugs became available to multiple sites simultaneously.

SYSTEM SECURITY. Security for a distributed system is more complex than for a standalone system. For example, an Ethernet network analyzer can record or modify network traffic, including passwords and data. Since the users of a network are at a distance from one another, they could take the liberty of impersonating legitimate users without the risk of discovery posed by physical trespassing.





[2] A circuit simulator application (left), which may reside anywhere in a distributed computing environment (DCE), employs the DCE directory service to look up the addresses of a database server and test data it requires. Here the database server process resides in computer m *in cell* B, *the test data in computer 2 in cell* A.

[3] When a user logs in from a computer (client) in the DCE, a security service—a special program in another computer in the same cell—checks and authenticates the user (above). Later in the course of executing a program, the client may make a remote procedure call. That request is automatically routed to a server that carries access control lists (ACLs)—lists of users allowed access to specific databases in which the procedure may reside. Inclusion of a name in an ACL allows that user access to the data associated with that ACL.

OSF DCE uses encryption to avoid these and other security problems. Each cell maintains a protected registry of users in that cell and their encrypted passwords. Users and servers are authenticated (verified) by a special protocol that acts as a deterrent to impersonation. Users obtain security credentials for all OSF DCE services from a single network login to the authentication server—a computer program that keeps track of the identities and password information of users—as opposed to logging in once for each service.

Using the authentication system, servers determine which user is attempting to receive information or perform an operation. The server then refers to an access control list (ACL) to determine whether this user has rights to that information or operation. For example, the OSF directory service maintains an access control list for each resource name, and this list determines which users can do look-up operations on that name. Each file and directory in the OSF DCE file system has an access control list, too [Fig. 3].

Cells cooperate to grant users rights in cells other than the one that registers them, so a single network login can allow access to other cells. Cell administrators—those responsible for the part of the network included in a given cell—can limit such accesses from foreign cells, or, in the default configuration, can prohibit them altogether.

The circuit simulator in the example is run by a user registered in his or her cell and with rights to certain information. In order to access this information, the circuit simulator sends authenticated requests to the database servers. The servers reject attempts to access information by unauthenticated users (system penetrators) or unauthorized users (those not approved for access).

SUPPORTING NEW APPLICATIONS. Network computing encourages the creation and deployment of distributed applications by means of a distributed programming technique. The technique used in the OSF DCE is the remote procedure call (RPC). With RPC, a user can invoke a procedure on a remote system—one in the next room or even thousands of kilometers away—in a manner that looks like a local procedure call. The system moves arguments to the remote procedure, and returns its results. The RPC mechanism also handles most interoperability considerations, such as synchronization, data encoding, timeouts, and security information. Timeouts occur when a computer fails to respond within an allotted time as a result of computer or network failure, overload, or any other reason.

An RPC server is the remote equivalent of a library of procedures. An RPC client is the calling program. Clients and servers locate each other with the help of the directory server through a process called binding. RPC clients also use remote procedure calls to communicate with security servers to obtain authentication.

In practice, the OSF DCE programming capabilities allow robust distributed applications to be written in a matter of days, rather than weeks or months. They streamline the effort by automatically generating network protocols that correctly handle multivendor operation, naming, security, and error recovery.

COMMUNICATING CELLS. A basic DCE configuration has two cells. DCE software is installed on each computer in the cells to provide the basic software for remote procedure calls used to access services offered on any computer within the DCE. All computers use remote procedure calls to communicate with each other as needed by applications. Different brands of computers can be used within and between cells.

Each cell maintains its own directory, security, and file services on centralized machines. Communications within a cell are obviously faster than between cells, since fewer servers are involved. Servers can be replicated (duplicated) to handle large networks, and to reduce server downtime. Servers can be managed from any point in the network.

And what about the performance of a DCE? Depending on network load, a remote procedure call typically takes only a few milliseconds, over and above the processing time, which has to occur whether done locally or remotely. It is generally a good idea to design an application to depend on only part of network capacity.

RELIABILITY THROUGH REDUNDANCY. As to system reliability, it can be improved if the system is set up so that each of several computers provides all essential services, such as directory, authentication, or file service. Then if one is down, the system may still function. If any essential services are available only on one computer, in contrast, the system will not operate if that computer is down. Distributed computing reliability depends on the underlying network reliability.

Granted, the administration of a distributed system is more complex than the management of a single, local system, but a well-designed distributed system can be easier to manage than a collection of traditional systems with the same number of computers.

Finally, the price paid for distributed computing in terms of memory allocation is not all that high—its functions require anywhere from 1 to 10 megabytes for software and data on each participating computer, depending on the operating system in use and the number of services offered. Large server configurations may require more.

TO PROBE FURTHER. To learn more about network computing, consult *Computer Networks*, by Andrew Tanenbaum, Prentice Hall, 1989, a general-purpose text on the network foundation of network computing. *Distributed Systems*, edited by Sape Mullender (ACM Press, 1989), provides an in-depth look at distributed-systems issues, including remote procedure calls, security, and file systems.

Information about the OSF DCE is available in a variety of papers and documents from OSF, including the *Introduction to DCE*, by Jennifer Steiner, Prentice Hall, 1992. Contact this article's author at 11 Cambridge Center, Cambridge, Mass. 02142, for more information.

Posix standards are discussed in "IEEE Posix: making progress," *IEEE Spectrum*, December 1991, pp. 36–39.

ABOUT THE AUTHOR. Douglas Hartman is director of Distributed Computing Environment (DCE) engineering at the Open Software Foundation Inc., Cambridge, Mass., where he manages DCE architecture and implementation. His interests include operating systems, networks, and applications of technology. ◆

Capabilities of networking software today

	Multi-vendor support	Wide-area network (WAN)	Security	Application program support
OSF DCE	•	•	•	•
Netware	•		•	•
NFS	•			•
Domain		•	•	•
DECnet		•	•	•
Internet	•	•		
OSI-based software	•	•		

The table does not include entries for technology such as IBM's SAA, Digital Equipment Corp.'s NAS, or Unix International's Atlas, which all incorporate the Open Software Foundation's Distributed Computing Environment (OSF DCE).

Combined effort for open systems

The Open Software Foundation (OSF) was founded as a not-for-profit R&D organization to develop software that would allow hardware and software from different vendors to work together. Today OSF has more than 330 members—hardware and software vendors, end users, and university and research organizations—working cooperatively to further the adoption of open systems.

OSF provides "enabling technologies," software that allows system and software suppliers, as well as programmers in end users' organizations, to build on a common software foundation. OSF's open computing environment includes the OSF/1 operating system, the OSF/Motif graphical user interface, the OSF Distributed Computing Environment (DCE), the OSF Distributed Management Environment (DME), and the OSF Architecture-Neutral Distribution Format (ANDF). Adopted by vendors worldwide, these technologies comply with relevant industry standards and specifications such as those of IEEE Posix, which provide interoperability among diverse systems. —*D.H.*

Elizabeth Laverick

After an exemplary 34-year career in avionics and administration, Elizabeth Laverick hopes to show other women the way to the top

"I never determined my career. It just sort of happened," said Elizabeth Laverick, the only woman ever named an IEEE Fellow in the Section covering the United Kingdom and Republic of Ireland.

What "just sort of happened," as Laverick modestly puts it, has been one of the more remarkable engineering careers in post-World War II Britain. There are almost too many milestones to count, and the unassuming, earnest Laverick is not the type to rattle them off. But over the course of a 5-hour interview, a few leak out: the first woman to earn a Ph.D. in a scientific curriculum at the University of Durham in the north of England, where her specialty was audio frequency dielectric measurements; the first woman to make it into the top management echelon of a major British defense contractor; and the first woman to serve as Deputy Secretary of the UK's Institution of Electrical Engineers (IEE). As deputy secretary, Laverick held the second-highest staff position in the IEE, the British counterpart of the IEEE.

WAR AND REMEMBRANCE. Like many other British engineers of her generation, Laverick's choice of career was profoundly influenced by World War II, and the heroic role played by the developers of radio, radar, and other technologies. To the teenager in Amersham, about 55 km northwest of London, the war was never very far from home. One night in 1940, for example, German pilots bombed a searchlight at a nearby small British Army encampment. Hearts pounding, the 14-year-old Laverick and her older sister jumped out of bed to watch the hubbub in their otherwise sleepy village.

"I remember mother calling out, 'You are under your beds, aren't you?,' " Laverick said. "We said yes, but of course we were craning out of the windows."

Glenn Zorpette Senior Associate Editor

At 16, Laverick, who had excelled in mathematics at Dr. Challoner's Grammar School in Amersham, was ready for college. But her first choice—Durham—refused to let her in until she was 17, so Laverick applied for a job as a technical assistant at the Radio Research Station at Ditton Park. Traveling to Ditton Park on the morning of her interview, Laverick and her mother got lost. All road signs in the area had been taken down as a precaution against a German invasion.

Half an hour late for her interview, and convinced she had already lost the job, Laverick was "ushered into a room with five or six elderly gentlemen, or what I thought were elderly gentlemen." During the interview, a man with a thick beard asked her a question, and had to repeat it two more times before Laverick could make out what he was saying. The question was: "Is your hearing good?"

"I thought, surely, that's that," she recalled with a laugh. The bearded gent wanted to know about her hearing because the job would entail listening to radio signals. "In those days, my hearing was excellent," she said. "I was just nervous, and probably couldn't hear him through that beard."

Much to her surprise, she was offered the job. In an era when global communications depended on high-frequency radio, an important part of the laboratory's work involved ionospheric measurements and experiments, particularly on the E and F layers. She also worked on projects in radar and radio direction finding, some led by Reginald Leslie Smith-Rose, a radio pioneer who would later give Laverick her first job reference.

> Being a woman physics student didn't seem odd because 'it was wartime, and everything was odd'

Although Laverick was assigned to an office at the research laboratory, where she plotted and analyzed data, she was allowed one day a week in the laboratory. "It was the first time they allowed a woman into the laboratory," she recalled. Thus began a 20-year stretch in military electronics and avionics, followed by a 14-year career with the IEE.

FATHERLY ADVICE. Laverick credits her father with steering her toward physics and radio rather than mathematics, which was her first love. A pharmaceutical chemist who later managed his own baby-foods plant, her father intensely valued self-reliance. He had moved to a small house on a plot of just over half a hectare in then-rural Buckinghamshire, where the the family grew its own produce and raised chickens and ducks, and Laverick spent a happy childhood.

"Father was very keen that my sister and I become sufficiently qualified in our fields, whatever we chose, to look after ourselves no matter what happened," she explained. If she concentrated on mathematics, she thought her job options after college would have been limited to teaching. And if she were to become a teacher, marriage would have made her financially dependent on her husband: at the time, married women in Britain were not allowed to teach or hold any government job.

So physics and radio it was. Besides Laverick, 20 young men began the physics program at Durham in 1943, and when it came time to choose laboratory partners, Laverick was the odd woman out. Not that she was intimidated by being the only—and first—female physics major at Durham: "It didn't seem odd at the time because it was wartime, and everything was odd," she said. "So I didn't take notice of it."

It also helped that she was for the most part better prepared than most of her male classmates. During her year at the Radio Research Laboratory, she had learned to solder, test vacuum tubes, and operate other test instruments, which gave her a "great feeling of confidence."

Laverick characterizes herself as "a very shy girl" during her undergraduate years. The record shows she was also an academically outstanding undergraduate, who played violin in the orchestra at Durham Cathedral and did volunteer work at the local YMCA. After completing a three-year B.Sc. course with honors, she began doing research on audio frequency dielectric measurement, which led to a Ph.D. from Durham in 1950.

Shortly after receiving her Ph.D., she was hired by Sir Robert Clayton at GEC-Stan-

Photograph by Colin Antill

 0018-9235/92/$3.00©1992 IEEE

Vital statistics

Name: Elizabeth Laverick
Date of birth: Nov. 25, 1925
Place of birth: Amersham, Buckinghamshire, England
Height: 172 cm
Family: one sister, Frances
Education: B.Sc., 1946; Ph.D., 1950, both from Durham University
First job: technical assistant, grade 3, Radio Research Station, Ditton Park (1942)
Leisure activities: embroidery, home improvement, gardening, reading, listening to music, traveling, visiting stately homes
Musical instrument: violin
Favorite composers/music: Brahms, Mozart, Fauré, Beethoven string quartets
Favorite authors/books: Max Ehrmann's *The Desiderata of Happiness* (a collection of philosophical poems); Wilbur Smith; Jean Auel; Jean Plaidy; James Michener
Memberships and awards: Fellow, IEE (UK); Fellow, IEEE; Fellow, Institute of Physics (UK); Fellow, Royal Society of the Arts; President, Women's Engineering Society (1967–69)
Management credo: "Management is getting the best out of people, and to do that you have to help them get the most out of themselves. It means encouraging young people to develop their own potential as far as they can, and perhaps aim a bit higher than they might achieve."

more (now Marconi Defence Systems Ltd.), where she worked in microwave antenna design. An energetic young woman who liked "climbing up and down microwave towers, and being in the open air," she enjoyed working with Clayton, whom she still considers a mentor. But she noted that even with a Ph.D., she started off at only £400 a year at GEC-Stanmore—£50 less than men with bachelor's degrees were then being paid.

Forty-two years later, she said, surveys show that the salaries earned by British women engineers are still lower than those of their male colleagues. Even allowing for the fact that "a lot" of women cut their careers short or take an extended leave to raise children (which drags the median salary down), "it's still pretty clear that there's a discrepancy," she said.

CAREER MOVE. The opportunity to concentrate on research and move into management led her in 1954 to accept a position as a section leader with Elliott Brothers Ltd., where she worked on millimeter-wave instrumentation.

Among the many projects she was involved with, or in charge of, at Elliott, one that stands out was an intrusion-detection system built around an off-the-shelf seismic sensor. Signals from the sensor were converted into the audible range, and intrusion in an area created a distinct sound and triggered alarm lights. Her first project to go into practical use, it was used at a British military base in Burma (now Myanmar) in the late 1950s, and later at a prison in Wales.

Later on, as head of Elliott's 40-member Radar Research Laboratory, Laverick worked extensively on a system for monitoring aircraft landings, from touchdown to roll-out. The system was used in the late 1960s to monitor aircraft landings at London's Heathrow airport, alerting air-traffic controllers when an aircraft's landing system was off center.

In the 1950s, for eight years, Laverick was married to a physicist she had met during her graduate studies at Durham. The experience seems to have helped shape her views on juggling professional and personal concerns, views she now shares with young women starting out in engineering. "If you want to combine career and family," she tells them, "find a partner who agrees with you. Because if it's not a joint venture, you'll break up your career or your marriage."

SURPRISE PROMOTION. The late 1960s was a period of almost incredible activity for Laverick. In 1968 she was named general manager of Elliott Automation Radar Systems, much to her own surprise. "It had never seemed to me that I'd break through into general management," she recalled. Between 1967 and 1969, she was president of Britain's Women's Engineering Society, and in 1969 also served as an IEE council member. When asked how she managed to hold down so many responsibilities simultaneously, she answered simply: "It was a time when I found that the more I did, the more I could do."

The acquisition of Elliott by Marconi in 1968 brought a whole new set of challenges, not the least of which involved defending and championing many of Elliott's radar projects at a time when the parent company was inclined to curtail them or merge them with those of its own companies. Sir Robert Telford, who was then in charge of merging Elliott (and other companies) into what is now the GEC-Marconi Co., recalled that both companies were hard at work on infantry radar systems for detecting ground targets, "so there was the question of who would carry on with the work." Laverick "fought a very skillful battle to retain it in her particular laboratory, and I agreed to that at the end of the road," he said.

The "very shy girl" at Durham had become, in Telford's words, "a very determined person, extremely competent, and very, very skillful in her arguments and handling of the issue. . .She was good, no doubt about that."

> Only with time does the woman engineer realize that 'there is still quite a lot of prejudice'

Another of the projects that had originated at Elliott was the radar for a proposed airborne advanced early warning system called AEW (later Nimrod). But in 1971, the British Government terminated the research contract for AEW, which prompted Laverick to do some soul-searching. "That was when I began to start wondering, well, do I really want to do this for the rest of my life?"

At about the same time, Laverick learned that the IEE was looking for a deputy secretary. She had been active in several professional organizations, including the IEE, since the 1940s and "felt quite strongly about the services the institution provided, or didn't provide."

"By then, I was more interested in management than technical concerns, and management within the institution was fascinating," she explained. Like the IEEE, the IEE is a heterogeneous group whose inclusion of academics, as well as those interested in standards, publishing, professional issues, and technical legislation and regulation, inspires cross-fertilization and spirited debate.

After getting the job at the IEE, Laverick took a special interest in career development issues, helping initiate programs in televised instruction and create courses on advanced manufacturing, electrical wiring regulations, and other subjects.

Five years before she retired from the IEE, Laverick moved back to her native Amersham to help care for her elderly parents, who still lived in the same home she grew up in. After they died, she and her sister sought out a developer who agreed to build a nursing home on the site.

Today, Laverick can see the two-story nursing home from a window of her own residence, a 1920s bungalow whose interior she has had completely redesigned. "If I had a second choice, it would be to be an architect," said Laverick, now in the midst of a major landscaping project.

WOMEN'S CHAMPION. These days, when not poring over designs for a fish pond she plans to put on her property, Laverick is likely to be involved with some issue affecting engineers, particularly women engineers. Out of the blue, she brings up the last IEEE election. "For the first time ever, I voted," she said. "I voted for Martha Sloan. I felt sufficiently strongly that she'd done a lot within IEEE, and it would be great to have a woman in that position." Clearly delighted with Sloan's success, she hopes to meet the IEEE President-Elect someday.

Even in retirement, Laverick still pursues one of her strongest interests, that of improving the lot of women in engineering. "Unless we're willing to act as role models, and go out and tell girls about engineering as a career, we're not going to increase in number," she said, "because there is still a lot of prejudice among parents and teachers against it [encouraging girls to pursue technical professions]." According to Britain's Engineering Council, only 1 percent of registered British engineers are women, as compared with 8.2 percent in the United States.

One of her perennial concerns is increasing membership in the Women's Engineering Society, which now totals about 800. "The proportion of women engineers who join is too low," she said. "There are over 4000 women engineers just in the IEE, so I presume there must be at least 15 000 out there" in the United Kingdom.

"Often the woman engineer, particularly the young woman graduate, is pretty confident that she's going to manage, and she doesn't want to be thought of as different," Laverick said. "It's only with time that she realizes that there is still quite a lot of prejudice, and we really don't have equal opportunity yet." She herself joined the Women's Engineering Society in the 1950s but did not become very active in it until the 1960s.

She still gives talks to girls and young women about engineering, although less often now, in the belief that "it's best to let the younger women do it." Always, she said, her talks are based on her own experiences —"what I found good about my career."

"Engineering is all about people," she tells them. "It's not some abstruse technical endeavor; you're thinking out solutions for the kinds of things people want." ◆

Jan. 28, 1958: a laser is born

The use of a diffraction grating for mode selectivity captured the imagination of Arthur L. Schawlow, one of the laser's inventors

Only a few decades old, the laser—a device for light amplification by stimulated emission of radiation—has revolutionized many industries, including medicine, manufacturing, construction, and printing. Its predecessor was the maser, which dealt in microwave amplification and so emitted at longer wavelengths than light.

The maser was conceived in 1951 by Charles H. Townes, then a professor at Columbia University, New York City, and first demonstrated by him in 1952. The steps that led from the maser to the laser owed much to his working relationship with one of his research associates at Columbia, Arthur Leonard Schawlow, a Canadian physicist who was studying the application of microwave spectroscopy to organic chemistry. Though Schawlow did not work on the maser, he kept an eye on it through his close link with Townes, with whom he was writing a book on microwave spectroscopy. Later, at Bell Telephone Laboratories in Murray Hill, N.J., Schawlow had begun by the summer of 1957 to think of developing a concentrated beam of far-infrared (not visible) light.

By this time, Townes was a consultant for Bell Labs, often conferring with Schawlow. It was at one of their meetings that the two first seriously debated how to develop some kind of infrared or even visible-light laser.

Some decisions were simple. Schawlow opted to excite the atoms of potassium vapor, because potassium was the only substance he knew to have the first and second lines of its spectrum in the visible range.

Mode selection, however, proved one of the biggest hurdles. It involved designing the resonator cavity so that it would reinforce only the waves of the desired frequency. Townes downplayed the problem, believing that once the atoms got excited, one or more modes would dominate over the others. Schawlow, though, felt just one mode should be selected because otherwise the light might emerge in all directions and over the whole bandwidth of the amplifying spectral line.

Of the many schemes Schawlow concocted to select a mode, one of particular interest is his notebook entry on Jan. 28, 1958 [see illustration]. The entry describes how mode selection could be achieved through the shape of the resonator's cavity. It underscores the finding that mode selectivity could be increased by using diffraction gratings for the resonator walls (this was done nine years later in the first wavelength-tunable dye laser, built by Bernard H. Soffer and B.B. McFarland at Korad). Because the resonator cavity also provides stronger coupling between the light waves and atoms, the effects of stimulated emission are enhanced, the entry adds.

Schawlow later realized that to select one mode, all that was necessary was to select a direction for the waves. The two mirrors on opposite ends of the resonator would then cause the waves to go back and forth a number of times and generate a high mode selectivity. So he got rid of most of the resonator, keeping only its two ends.

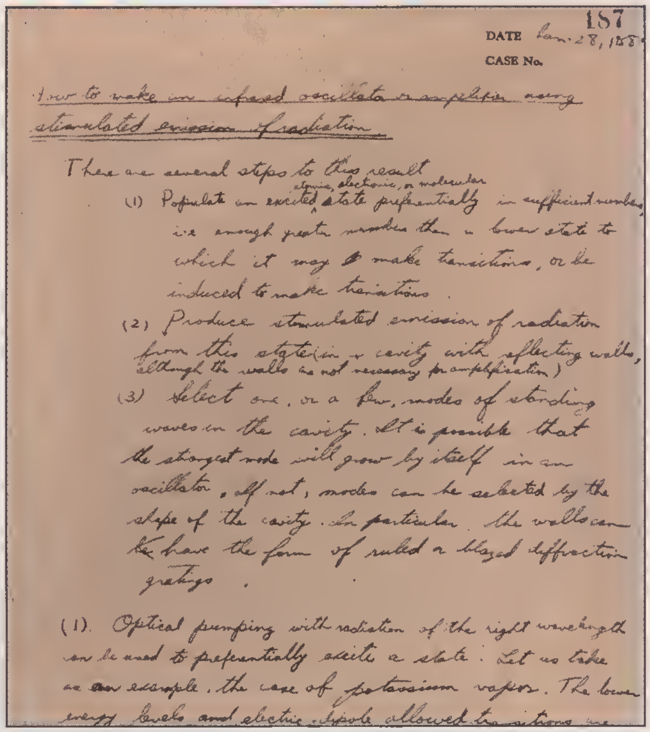
At this point, Schawlow and Townes believed they had thoroughly analyzed the theory behind the laser and presented their ideas in their paper, "Infrared and Optical Masers," which was published in *Physical Review* (Vol. 112, 1958, pp. 1940–49).

In 1958 Schawlow discovered that the satellite lines at 701 and 704 nm, which accompany the R (red) line in the spectrum of concentrated ruby, were caused by the presence of chromium ion pairs. He also found that their lower energy levels were enough above the ground level that ions excited to those levels could be made to fall to a lower level by cryogenic cooling. With these lower levels essentially empty, he suggested there would be no absorption at these wavelengths, and so any ion pairs excited to the upper state of either satellite line would produce some amplification by stimulated emission—in this case by cooling. (In contrast, the R lines start out with nearly all of the chromium ions in the lower energy level, so that more than half of them would have to be excited before any optical amplification could begin.) An attempt with a low-power flash lamp failed.

After another pioneer in the field, Theodore H. Maiman, a researcher at the Hughes Research Laboratories, then in Culver City, Calif., demonstrated the first ruby laser on May 16, 1960, Schawlow attempted his cold ruby experiment with a bigger lamp.

That proved to be the solution. As Schawlow had predicted, he and co-worker George Devlin found that, at liquid-nitrogen temperature or below, these two satellite lines did indeed have a lower threshhold for laser action than the R line in a ruby crystal with 0.5 percent chromium. The optical maser that Schawlow had analyzed in 1958 finally worked.

On March 22, 1960, the two were issued U.S. patent No. 2 929 922. Soon after, several companies produced the first lasers. For their contributions, Townes shared the Nobel Prize in Physics in 1969, and Schawlow shared it in 1981. ◆


187
DATE Jan. 28, 1958
CASE No.

How to make an infrared oscillator or amplifier using stimulated emission of radiation

There are several steps to this result

(1) Populate an excited atomic, electronic, or molecular state preferentially in sufficient numbers, i.e. enough greater number than a lower state to which it may make transitions, or be induced to make transitions.

(2) Produce stimulated emission of radiation from this state (in a cavity with reflecting walls, although the walls are not necessary for amplification)

(3) Select one, or a few, modes of standing waves in the cavity. It is possible that the strongest mode will grow by itself in an oscillator. If not, modes can be selected by the shape of the cavity. In particular, the walls can have the form of ruled or blazed diffraction gratings.

(1). Optical pumping with radiation of the right wavelength can be used to preferentially excite a state. Let us take as an example, the case of potassium vapor. The lower energy levels and electric dipole allowed transitions are

Arthur Schawlow's notebook entry dated Jan. 28, 1958, describes how to induce mode selection in a resonator.

George Likourezos Editorial Intern

0018-9235/92/$3.00©1992 IEEE

Surviving hell and high water

Electronic equipment can often be rehabilitated after a fire or flood, but it helps to design it to minimize damage in the first place

Smoky dirt and soot coat all the printed-circuit boards and manufacturing equipment, and some items are wet from the water used by the fire department. So half a million dollars' worth of electrical and electronic equipment is now scrap, right?

Not if you act fast. If corrosion—the biggest enemy—can be stopped in the first 24–72 hours, then in at least three cases out of four the equipment can be cleaned and be up and running again as reliably as ever. On average, reclaiming equipment costs only 15 percent as much as replacing it, and usually gets it back in service sooner. In a recession the savings this means on insurance premiums and capital expenditures can be crucial.

Moreover, experience has shown that some equipment designs suffer less than others from smoke, water, and corrosion, suggesting ways that engineers can deliberately design equipment to minimize its vulnerability to fire or water and to allow it to be cleaned and put back to work.

SURPRISINGLY OFTEN. More often than managers like to admit, electric and electronic equipment in offices, banks, warehouses, power stations, or on manufacturing floors is ravaged by battery acid, fires and smoke, floods, earthquakes, electric shorts, lightning strikes, and other catastrophes. In the small state of New Jersey alone, the U.S. subsidiary of just one damage management and reclamation company, Imbach U.K. Ltd. (headquartered in Aldridge, West Midlands, England), responds to five or six incidents per week. Worldwide there are close to a dozen such companies, each with offices in a number of countries [see table, p. 47].

The most common type of damage they handle is the sooty film that smoke leaves on equipment, even in rooms not touched by fire. The next most common is damage from water from building sprinkler systems, fire hoses, or even leaking radiator pipes in the ceiling overhead.

Corrosion proceeds most rapidly right after exposure to fire, smoke, or water. The longer the exposure lasts, and in the case of fire, the higher the temperature reached inside the equipment, the less likely the hardware is to survive.

In all cases, the first step in stopping corrosion is immediately disconnecting the damaged equipment from the power supply—something most users can do by throwing a master power switch. Not only does that rule out further destruction from electric shorts—it also erases any voltage potentials within the circuitry that would otherwise plate contaminants onto circuit boards and backplanes.

Next, the ambient humidity must be reduced to below 50 percent. Although smoke does little damage while the fire is raging, the particulate residue left after the smoke has dissipated contains chlorides (from burning polyvinylchloride insulation and cabling and from Halon fire extinguisher compounds in high heat) and sulfides (from burning paper). All are corrosive byproducts of combustion that eat away at metal contact surfaces in the presence of oxygen and moisture. So reducing the humidity slows the corrosion.

> Reclaiming equipment, so that it runs as reliably as ever, may cost only 15% as much as replacing it

Ideally the equipment should be transported as soon as possible to a clean, air-conditioned, and humidity-controlled environment, such as the laboratory of one of the damage management and reclamation companies. Note that the task is one for trained professionals only; otherwise, personal injury, further damage to the equipment, or invalidation of warranties or service contracts may occur.

If moving the equipment is not possible, then the site housing it should be sealed off from the outside elements. It should have plastic sheeting rigged up around its doors and windows so that dehumidifiers may be brought in. Under no circumstances should the building's general recirculating air-conditioning system be used to flush out remaining smoke and moisture; all that does is spread the contaminants to other rooms and floors, so that the building's entire air-conditioning system and ductwork may have to be cleaned as well.

HOW BAD IS IT? Once the environment is stabilized, the damage management team will analyze the nature and extent of the contamination so the owners can weigh the feasibility and extent of restoration.

A fast but good electrochemical test at the site itself assesses the concentration of chlorides. A square centimeter on each of 20–30 contaminated surfaces is wiped with a cotton swab dampened with distilled water. Each swab is then crushed in a solution of distilled water and sodium nitrate, and the concentration of chloride measured with an ion-selective electrode. Generally speaking, a contamination of less than 50 $\mu g/cm^2$ means the equipment would be very easy to clean by hand; between 500 and 1000 $\mu g/cm^2$, on the other hand, means the equipment would have to undergo repeated washes and rinses, being checked for contamination at the end of each cycle.

If chloride contamination exceeds 1000 $\mu g/cm^2$, a second test is necessary. Various surfaces are sampled by pressing a special sticky conductive tape against them; the tape samples are then placed in a vacuum chamber where they are analyzed by scanning electron microscopy and electron dispersive spectroscopy. The scans yield qualitative and semiquantitative values of all the elements present, from sodium to gold and heavier. X-ray techniques, such as X-ray fluorescence and X-ray absorption, can provide similar information.

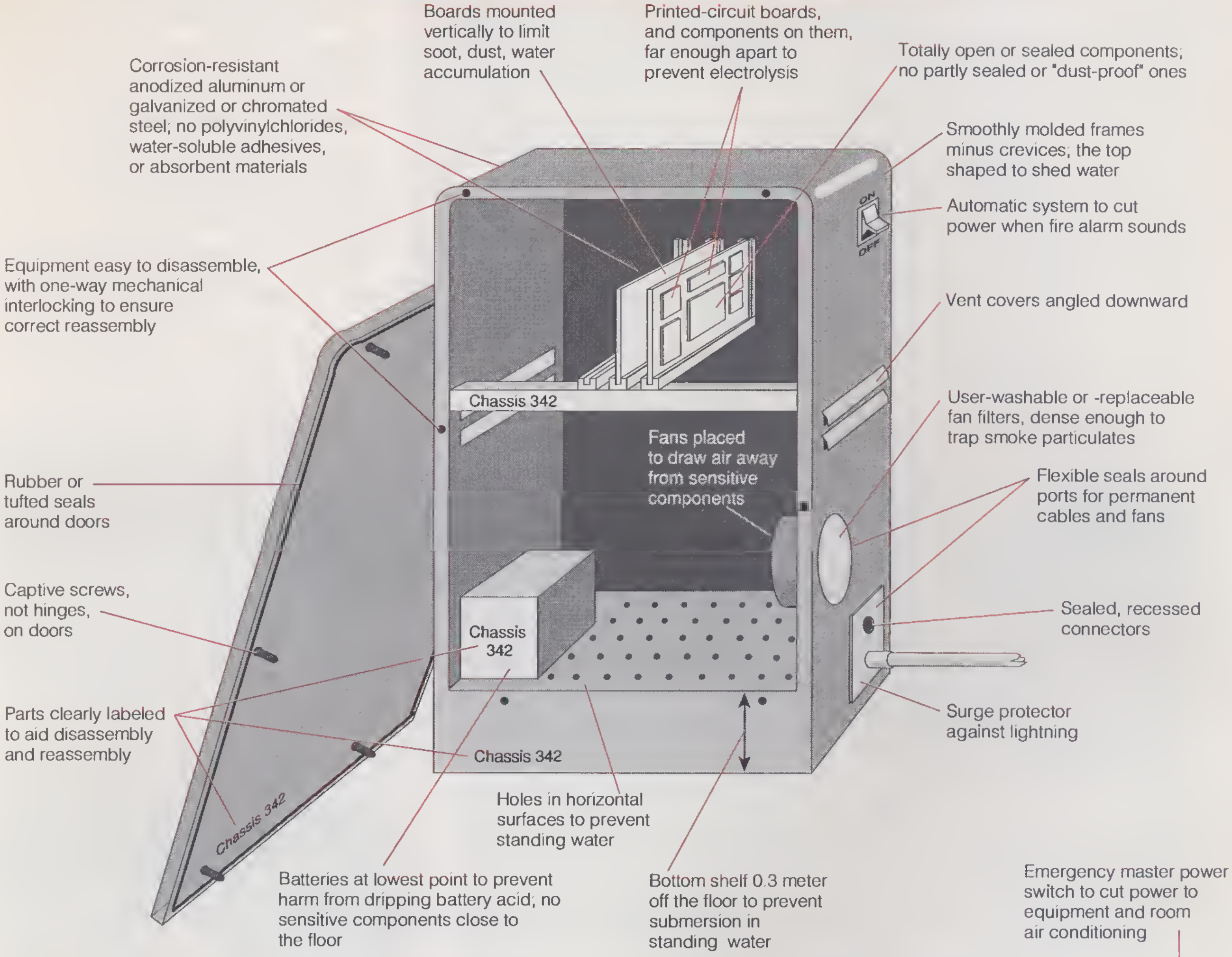
When the composition and concentration of the contaminants are known, a detailed and practical plan for the restoration of the equipment can be devised, including: which pieces can be salvaged without a loss of reliability (and which others are now scrap), which should be reclaimed first, what cleaning techniques should be used, how long the job will take, and what it will cost.

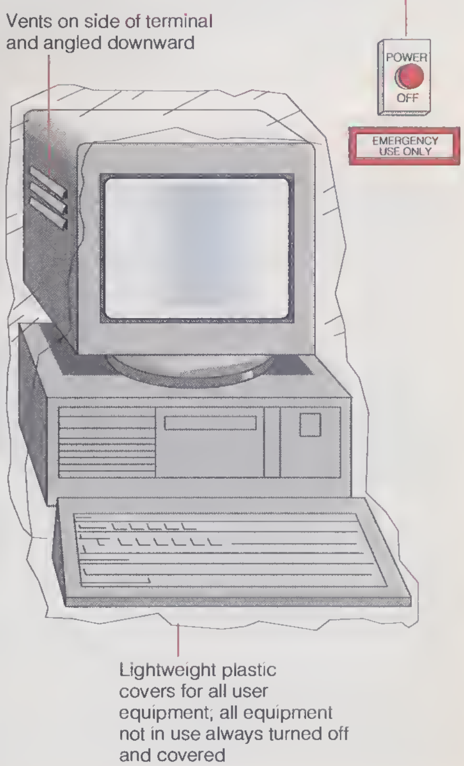
BEGINNING THE RECLAMATION. Once the necessary test samples are taken—a procedure taking up to a couple of hours—the damage management team will probably

Marvin Kurland Trenton State College

0018-9235/92/$3.00©1992 IEEE

Designing equipment to survive fire and flood





Source: Marvin Kurland

CHLORIDE DAMAGE TO DIODE

Damage analysis. A power diode was severely contaminated by chlorides released from polyvinylchloride (PVC) electrical insulation during a fire (left-hand photograph).
Restoration technique. After being hand-washed with soap and deionized water, the diode not only looked but was better—test results indicate no loss of reliability and operating characteristics. (The serial numbers do not show on the cleaned diode because the right-hand photograph shows the other end of the diode.)
Design lesson. Avoid the use of PVC insulation. At high temperatures it emits copious amounts of chlorides so corrosive that they often pit surfaces beyond repair. In this case, the damage-management team was able to act within hours, minimizing the destructive corrosion.

spray connectors, backplanes, and circuit boards with a water-displacing protective oil. The oil leaves a thin but easily removable coating to help prevent oxygen and moisture from contributing further to corrosion.

Contrary to popular belief, water in itself does not permanently ruin electronic equipment, which can be splashed or sprayed with it, or even submerged in it without irreparable harm. Water alone is quite innocuous—indeed, deionized water (which has about the same low surface tension as alcohol and essentially no conductivity) is used in cleaning much damaged equipment. The trouble is due to corrosive impurities from pipes or soot that mix with the water—hence the use of a water-displacing oil to limit the occurrence and extent of corrosion.

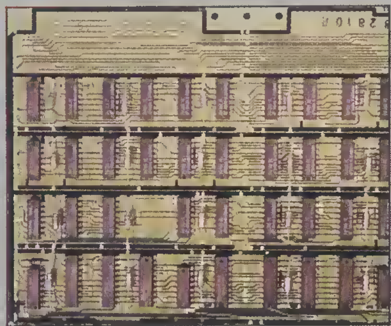
As soon as possible, cabinet doors should be opened, side panels and covers removed, and chassis drawers pulled out to drain the water off, something a user can do. Never, ever, should water-damaged equipment be placed in cardboard packing boxes or any other material that will trap moisture inside the chassis.

CLEANING PROCESSES. A damage management team will probably set up fans to move room-temperature air through the equipment to dry it out, taking care to keep the damp air flow away from other equipment. Technicians may also direct compressed, deionized air at low pressure (about 0.7 megapascal) to blow out trapped moisture or direct heated air from handheld dryers onto connectors, backplanes, and circuit boards.

Chassis and large pieces of equipment are disassembled and may be spray-cleaned by deionized water at low pressure (about 0.15–0.35 MPa). Circuit boards could also be washed by hand and gently scrubbed with a clean, soft brush in a continuous left-to-right, top-to-bottom motion to avoid any recontamination. If the equipment has been exposed only to chlorides, it may be washed with deionized water and mild detergent and rinsed with deionized water. If it has also been exposed to sulfides, it may also be washed with a solution of alkaline and deionized water.

In any case, the rinse is followed with a

SOOT AND SMOKE PARTICULATES



Imbach Corp.

Damage analysis. Smoke from a fire entered a graphics scanner system through an opening next to this processor. Relatively few smoke particles settled on the printed-circuit boards, which were mounted vertically. Note the splash marks (left-hand photograph) from the water from the firefighters or from condensation.

Restoration technique. The day after the fire, the unit was cleaned with mild detergent and deionized water at low pressure. The cleaned unit (right-hand photograph) was back in service the following day, functioning normally.

Design lessons. The vertical mounting of the circuit boards and the ease of disassembly and assembly were key to the success of this reclamation project.

HOT WATER DAMAGE

Imbach Corp.

Damage analysis. The left-hand photograph shows a printed-circuit board from a telephone switching system flooded when a pipe from a hot-water radiator ruptured on the floor directly overhead. Typically, water in such radiators is recirculated and is saturated with highly corrosive contaminants, which encrusted this connector.

Restoration technique. The equipment was cleaned with alcohol, mild detergent, and deionized water and then baked to drive out all the water from the relays. Although the cleaned circuit board (right-hand photograph) was put back into operation, exposed metal surfaces remained badly pitted from the chloride corrosion.

Design lessons. If the equipment had been protected from dripping water by an overhead shield, or not installed directly under a hot-water radiator, the loss would have been minimized.

ELECTROLYSIS

Damage analysis. A fire broke out on a floor above a microwave transmission system under bias and was extinguished with water. The water leaked down onto the transmission system, where it dripped onto the horizontally mounted circuit boards and remained for hours before it was discovered. Throughout, the system was under power. Note the carbonized contamination left on the boards by electrolysis, shorting, and arcing (top photograph). The bottom photograph shows a classic representation of electrolysis, where the carbonized contamination was magnetically aligned along a conductive bridge between components.

Imbach Corp.

Restoration technique. The system was a total loss, as power was on for hours with water present.

Design lessons. Had there been a shield above the system to direct the water away from the boards, most of them could have been saved. Had the boards been mounted vertically, or punctured with drain holes, the components would not have remained submerged. Had the spacing between components been a little wider, electrolysis might not have occurred. Also, had there been an automatic power shut-off triggered by the fire alarm, all the components could have been recovered.

low-pressure spray of alcohol to drive out the water. Note the mildness of this cleaning process compared to the rigors of manufacturing and wave soldering. The units are finally baked dry at 100 °C in special ovens, so as to remove all trace of moisture.

In disasters involving steam-generating power equipment, a more extensive spray cleanup at higher pressure (about 1.5–3.5 MPa) will be needed. This technique will also be used with the older, open type of transformer construction. Aside from that, the cleanup for heavy-duty power equipment is much the same as for delicate electronics.

BUSINESS DECISIONS. Since reclamation costs much less than new equipment, it is a desirable alternative, especially if equipment is fairly new and expensive. But as with all business decisions, money is not the only consideration.

The time it takes to reclaim equipment, for instance, is just as important as the cost. Some standard equipment can be purchased from stock and installed within 48 hours. In that case, replacement may be far faster than reclamation, which could take weeks if levels of contamination are high. On the other hand, specialized manufacturing or laboratory equipment might have to be custom-built, with replacement meaning delays of months or even a year. Then reclamation could be faster as well as cheaper.

Another major factor is the condition of the facility. If the physical plant has been damaged by fire or smoke, the floors, walls, ceiling, air-conditioning ducts, and much else must be cleaned and decontaminated to prevent recontamination of the new or reclaimed electronic equipment. The time needed to clean and certify the facility may be longer than the time needed either to reclaim or to replace the equipment, so that the reclamation decision becomes one to be made in terms of cost or preference, not of time.

More subtly, reclamation may affect warranties or service contracts. Some equipment manufacturers will not want their warranties or service contracts to continue after reclamation, feeling that they can no longer vouch for the equipment's reliability. With the help of the damage management company, that can be turned around. On the other hand, insurance premiums may remain lower after reclamation, as the cost to the insurance company was minimized.

In any event, companies should be aware that, yes, disasters can befall them as well as their neighbor, and have a corporate strategy and policy in place before the worst should happen.

DESIGNING RECLAIMABLE EQUIPMENT. A design engineer must work closely with both components and material engineers to mitigate the effect of fire, smoke, water, or chemicals on electronic equipment. Suggestions for design consideration are outlined in the figure on p. 45. As some of them cost more in the initial stages of design, the design team must do a trade-off analysis.

To amplify and add to some of the points made in the figure:

• On sealing components: this is especially important for surface-mounted devices. Potted components, which are sealed with an impervious material once they are mounted on a circuit board, are desirable. To be sure, if contamination creeps in, it will never come out—but the probability of contaminating these components is low.

• On minimizing the use of polyvinyl chloride (PVC) plastics: although PVC cables remain flexible at wide ranges of temperature and PVC is an excellent insulator, the plastic releases large amounts of highly corrosive chlorides when exposed to fire.

• On avoiding water-soluble materials or adhesives: they will be destroyed in any kind of spray used for putting out the fire or cleaning the equipment. Also, absorbent materials of any kind should be kept to a minimum because they will only harbor contaminated liquids.

• Finally, plastic covers for terminals and keyboards not in use go a long way in preventing much damage from smoke and water.

TO PROBE FURTHER. One of the first books published on the feasibility of using water to clean smoke-damaged electronics without hurting their reliability was the 133-page *Effects of Corrosive Smoke on Electronics*, by S. T. Olesen, published in January 1984 by the Danish Public Research Institute, Elektronik Centralen. Its address is Venlighedsvej 4, DK-2970 Hørsholm, Denmark; (45+42) 86 77 22.

Barry S. White, in his article "Corrosion Resulting From The Use Of Halocarbon Fire Extinguishants," published in *Industrial Corrosion*, Vol. 6, no. 1, pp. 10–13, 1988, was the first to describe the corrosive effects of Halon gas when used as a fire extinguisher in the presence of high heat.

The annual conference of the Property Loss Research Bureau is useful for learning the views of loss managers and others on property loss claims and reclamation versus replacement. The next conference will be held April 19–21, 1993, in San Antonio, Texas. For more information on the meeting, contact the bureau at 1501 Woodfield Rd., Suite 400, Schaumburg, Ill. 60173; 708-330-8650.

ACKNOWLEDGMENTS. For help with this article, the author extends his thanks to Manny Muinos of Imbach Corp., Plainfield, N.J., Max Klepp of Relectronic Service Corp., Totowa, N.J.; Joseph Colao of Electronic Renaissance Corp., Edison, N.J., and Kenneth F. Greenough of Restoration Technologies Inc., Scotts Valley, Calif.

ABOUT THE AUTHOR. Marvin Kurland (M) is associate professor of electrical engineering at Trenton State College in Trenton, N.J., where he coordinates the electrical engineering program. He has also taught at Rutgers University and the Newark College of Engineering in Newark, N.J. He has held engineering and managerial positions with Westinghouse Elevator, Singer, Supreme Automation, and Lockheed Electronics. Most recently, he was vice president of engineering with Imbach Corp., an international damage management company. Now he is a consultant for a number of insurance companies and damage management companies both in the United States and internationally. He is also a member of the National Association of Corrosion Engineers (NACE). ◆

Major international damage-management companies

Aeroscopic Engineers Inc.
5245 San Fernando Rd. W.
Los Angeles, Calif. 90039
213-245-3024

Disaster Recovery Team
Sobro Group
799 London Rd.
Westcliff-on-Sea
Essex, England 550 95Y
(44+0702) 471 481

Electronic Renaissance Corp.
105 Newfield Ave.
Edison, N.J. 08837
908-417-9090

Imbach U.K. Ltd. (headquarters)
Westgate, Aldridge
West Midlands, England WS9 8EX
(44+0922) 54144

Imbach Australia Pty Ltd.
29/8 Gladstone Rd.
Castle Hill, N.S.W. 2153
Australia
(61+2) 634 6855

Imbach Corp.
400 G Corporate Court
South Plainfield, N.J. 07080
908-755-8400

M.F. Bank Restoration Co.
3120 Medlock Bridge Rd.
Building J
Norcross, Ga. 30092
404-448-7250

Relectronic GmbH (headquarters)
Oskar-Messter-Strasse 8
8045 Ismaning-bmuhn.
Germany
(49+089) 960 76110

Relectronic Service Corp.
60 A Commerce Way
Totowa, N.J. 07512
201-812-1940

Restoration Technologies Inc.
124 Spreading Oak Dr.
Scotts Valley, Calif. 95066
408-438-7614

Nokia's rising star flickers

Made over from a supplier of rubber, paper, and cable to a key European high-tech player, Nokia saw its sales slide into a loss last year

When Nokia Corp. reached its centenary in 1965, the Finnish company had a great deal to celebrate. Having started out as a small pulp mill on the Tammerkoski River about 160 km north of Helsinki, it had grown into one of Finland's major industrial firms with manufacturing businesses in rubber, paper, and cable. Profits were steady, and the Finnish banks and insurance companies that held most of the company's stock were more or less content.

When in 1977 Kari Kairamo was elected president and chief executive, however, things began to change. Kairamo continued in the direction chosen by his predecessor, Bjorn Westerlund, focussing strongly on the company's fledgling electronics department. Formed to service Nokia's own computer systems, it had begun marketing its services first to Finnish and then to Scandinavian companies. In 1973 the department sold its first computer, the Mikko 2, for banking applications.

Fred Guterl Contributing Editor

Kairamo was also quick to spot another business opportunity. The state-owned telephone companies in Scandinavia, which already had very advanced fixed telecommunications networks, were beginning to fund R&D for radio telephone networks to reach customers spread thinly in remote areas far above the Arctic Circle. Kairamo, an insider in the small world of Helsinki industry, saw that early patronage from the telephone companies might just give Nokia a running start for exporting the technology abroad.

To an extent that at the time would have seemed incredible, Kairamo succeeded in transforming Nokia from a forest products company with a tiny electronics department in the 1970s to one of Europe's leading electronics firms. Sales for its last fiscal year ending Dec. 31, 1991, were 15.5 billion Finnish markkas (FIM), or US $3.7 billion (at about 4.2 FIM per dollar, though with a severe recession at home, the value of the FIM has been falling).

Nevertheless, Nokia had catapulted itself into being Europe's third largest television manufacturer, a significant player in the telecommunications industry, and a world leader in cellular telephones. It is also developing a high-definition television (HDTV) system and is a supplier for the European GSM (global system for mobile communications) standard for digital phone networks.

What is especially stunning about this growth is that Nokia managed it while leveraging its technological expertise: it conducts research only into key technologies, manufactures only the most crucial components, and relies on industry standard parts and third-party suppliers and manufacturers.

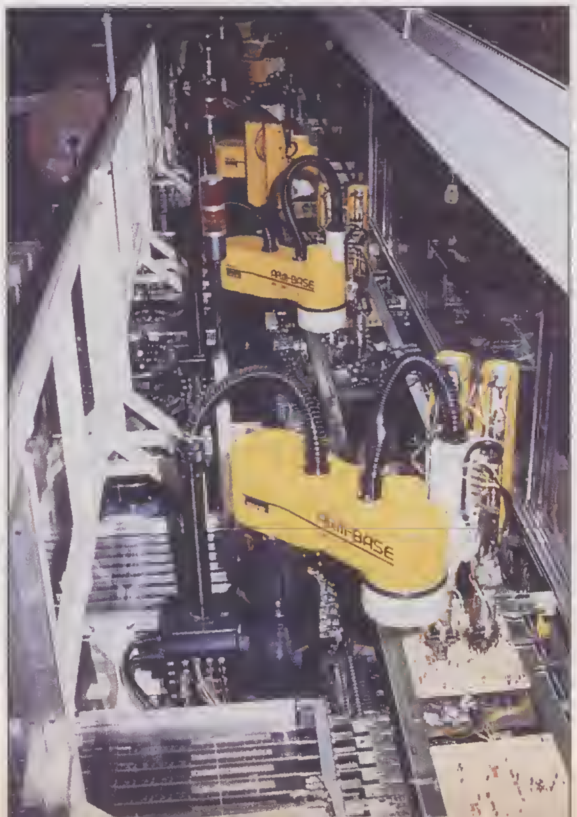
LEVERAGED STRUCTURE. This highly leveraged structure, a by-product of the company's rapid rise in electronics, is both Nokia's strength and its weakness. By buying much of its technology and manufacturing, it can react faster than many competitors to changing technologies and business opportunities. It is also betting on the ability of its product designers and systems engineers to stay at the forefront of their fields.

But Nokia's metamorphosis has come at a price. There was the social disruption that its employees suffered during the divestment of its old businesses and because of management mistakes in its new ones. And then Nokia's expansion left the firm overextended when the current recession hit more than a year ago. As a result, its 1991 sales of 15.5 billion FIM represented a 16 percent decline from 1990 (adjusted to take into account the sale of some businesses), and the company's first ever loss, of 211 million FIM. Sales have been in decline since 1989's peak of 22.8 billion FIM.

A decade earlier, that loss would have been inconceivable. The information industry then was posting tremendous growth throughout the world. To tap into that boom, Kairamo took a leading role in ushering in Finland's high-tech era, which, it was hoped, would remove Finland's dependence on forestry and put the small Arctic nation into the vanguard of European industry.

Kairamo himself seemed to embody a new breed of Finnish businessman. "Kairamo was a spectacular person," recalled Timo Ronkainen, an

Nokia 101 cellular telephone weighs in at 275 grams, including its own built-in battery charger.



Production lines like this one in Bochum, Germany, have helped Nokia become Europe's third largest manufacturer of television sets.

0018-9235/92/$3.00©1992 IEEE

analyst at Unitas Securities Ltd. in Helsinki. "He was dynamic. He worked extremely long hours. He had strong views and took big steps."

ONE MAN'S VISION. From research done in the 1970s, Kairamo nurtured a thriving telecommunications business. It supplied telephone switches and mobile telephones to Scandinavia and, with the introduction of the DX-200 digital switch in 1979, the equipment was sent to European and Asian markets as well. Sales that year reached 3.1 billion FIM.

Kairamo's vision was of a company that could exploit the synergy among several lines of business. He boldly acquired major European electronics companies—most notably, the Consumer Electronics Division of Standard Elektrik Lorenz AG (SEL), Stuttgart, Germany, for its television capability in 1987 and the Data Systems Division of L.M. Ericsson, Stockholm, Sweden, for its computers in 1988. To buy them, he sold whole sections of Nokia, mainly the rubber and paper products businesses, retaining the most profitable ones, such as tires, power and chemicals. By 1988, Nokia's sales were 21.6 billion FIM, with electronics accounting for 60 percent of that total—nearly 80 percent if the cables and machinery division was included. By 1991, that figure had increased to over 90 percent.

In computers and consumer electronics, however, rapid expansion threw the company into a state of crisis from which it is only now emerging. When Nokia acquired Ericsson's data business for 1345 million Swedish Kroner (US $224.2 million), the Scandinavian computer market was reaching saturation. The group was losing money, and when the general economy headed downward, opportunities for a fast recovery appeared slim. In 1988, for the first time in years, Nokia's corporate profits took a slide.

Euphoria quickly turned to gloom. Kairamo was bitterly disappointed. Said Ronkainen: "Nokia talked about reaching a $28 billion [US dollars] turnover. They wanted to conquer Europe. But their plan was a complete failure and they stagnated." In December 1988, Nokia suffered the additional trauma of Kairamo's suicide. The death of its visionary and charismatic leader at the age of 56 loomed large at the company and his absence is still keenly felt.

RETRENCHING. After Kairamo's death, Simo Vuorilehto became chairman and chief executive and Nokia entered a period of retrenchment. Last summer, for instance, International Computers Ltd. (ICL), London, a British firm acquired by Japan's Fujitsu Ltd. the year before, bought the data division for about US $400 million.

Vuorilehto is described by business associates as a conventional Finnish businessman—stern, formal, and lacking the flamboyance of his predecessor—whose pragmatism was seen as a necessary corrective. Vuorilehto will retire this June and be replaced by Jorma Ollila, the former president of Nokia Mobile Phones.

Milestones

1865 Fredrik Idestam establishes his Tempere Groundwood Mill and three years later builds a second mill in Nokia, Finland.

1871 Idestam incorporates as Nokia Oy.

1902 Nokia builds its first power-generating plant.

1919 Finnish Rubber Works buys into Nokia.

1928 Finnish Cable Works, owned by Finnish Rubber, begins producing telephone cable.

Glue line for boots at Finnish Rubber Works, 1933.

1948 Finland and USSR sign barter agreement.

1960 Electronics department formed to service company computers.

1964 Nokia produces its first radio phone.

One of Nokia's wood mills, 1942.

1967 Nokia merges with Finnish Rubber/Cable.

1973 First computer, the Mikko 2, for banking.

1977 Kari Kairamo is elected chief executive officer, starts turning Nokia into an electronics company.

1979 First analog telephone switch, the DX-200.

1982 First digital DX-200.

1984 Nokia acquires its first consumer electronics companies, TV makers Salora Oy of Finland and Luxor AB of Sweden.

1988 Field trials begin for an integrated-services digital network.

1988 Nokia acquires L.M. Ericsson's Data Division and the Consumer Electronics Division of SEL.

1991 The data group is sold to ICL.

1991 Nokia produces a cellular telephone based on Europe's digital Global System for Mobile Communications standard.

NOKIA

The present hard times have put Nokia on the defensive about Kairamo's strategy. The company has been criticized as being more of an assembler of other people's products than a *bona fide* manufacturer. Nokia executives reject such thinking. Competition in semiconductors has gotten stiffer, they said, and the trend toward open systems has fueled competition in the market for subsystems as well.

"A strategy of buying the best components [and subsystems] available from anywhere is not only beneficial but necessary," said former president and chief operating officer Kalle Isokallio. "You differentiate yourself on software, not components."

After selling the data division, Nokia's electronics focus has been narrowed to three main business groups: telecommunications, mobile telephones, and consumer electronics, primarily television. (Nokia has two other business groups: cables and machinery, and basic industries including chemicals, tires, and electric power.)

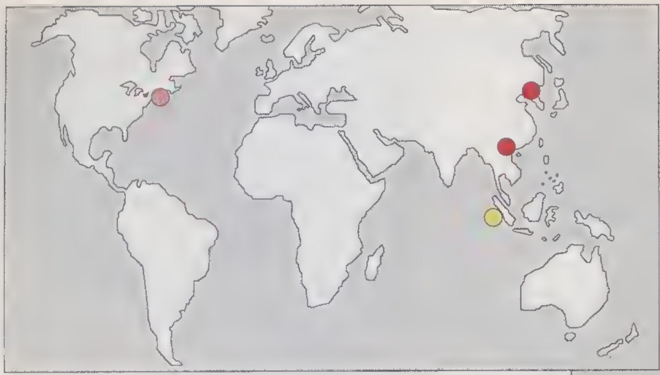
Perhaps the most difficult group to pull together was consumer products. It accounts for about one-third of Nokia's sales and last year had revenues of about 5.3 billion FIM, down 17 percent from the year before. The division was formed out of four acquisitions—Salora Oy of Finland, Luxor AB of Sweden, Oceanic SA of France, and SEL, which alone manufactured 1.2 million TV sets a year and was one of the largest producers in Europe.

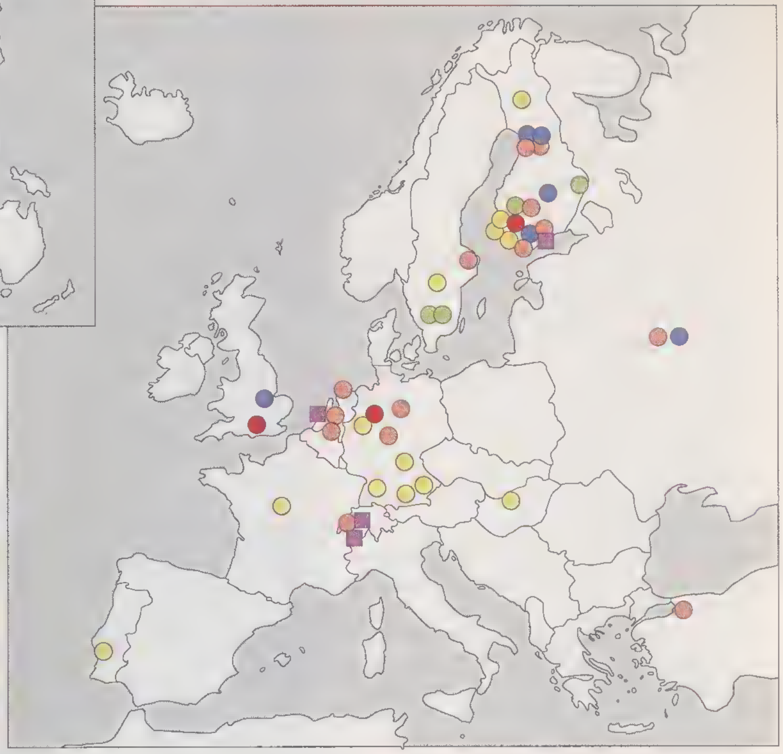
The acquisitions brought Nokia's annual volume of TV sets to 2 million units, which included 125 different models and 17 different chassis. Only recently has Nokia managed to trim the division. The purchase of Finlux this March provided Nokia with the opportunity to concentrate TV manufacturing in Turku, Finland, and in Bochum, Germany. A Salo, Finland, plant concentrates on monitors. (The Bochum plant also produces mobile phones.)

Currently, the company's color TV screens range from 14 to 33 inches, with the emphasis on up-market products such as digital, large-screen sets. In 1991 it introduced a 36-inch set with a picture ratio of 16:9 that can be broken up into several smaller independent ratios of 4:3 (pictures within pictures). This year, it will bring 28- and 32-inch 16:9 models to market.

Nokia entered the satellite dish market in

Nokia Corporation at a glance



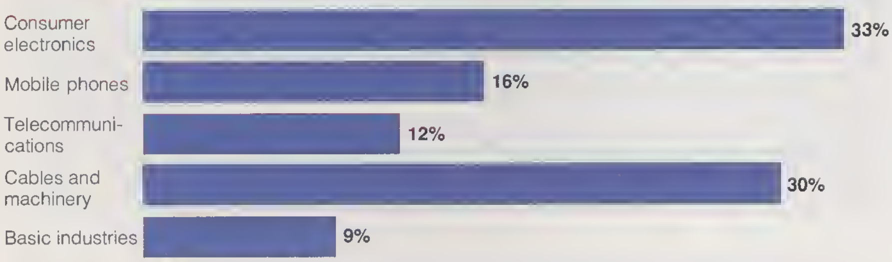


Significant figures*

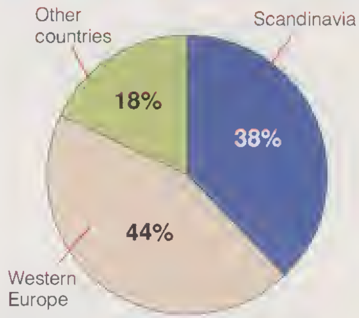
Sales revenue 1991	15.46 billion FIM
Decline from 1990	16%
Profit/loss 1991	–96 million FIM
Change over 1990	–109%
Employees 1991	29 000
Decline from 1990	22%

*Rate of exchange in 1991 approximately 4.2 Finnish markkas to the U.S. dollar.

1991 sales by business group



1991 sales by geographic area



the 1980s, when it began making MAC (multiplexed analog component) receivers for the PAL (the phase alternating protocol used in European television), D2MAC, and other protocols. (D2MAC is the intermediate standard approved by the European Commission before the implementation of full-scale high-definition television, or HDTV.) Nokia's sales of dishes grew somewhat in 1991, though the market declined some 10 percent.

FARMING OUT. Nokia farms out some of its television manufacturing to low-cost overseas producers—particularly for the large UK market, to which 200 000 television sets were shipped last year from plants in China and Singapore. Nokia also closed its videocassette recorder (VCR) factory in Europe, relying instead on manufacturers such as Sanyo, Sharp, and Akai.

The main reason this was done, said Heikki Koskinen, president of Nokia Home Electronics, a division of the Nokia Consumer Electronics business group, was that Nokia could not find the skilled labor needed to make the very small mechanical parts for the video heads. Europe no longer has a tradition of fine mechanical work, he said. Nokia's new VCR line is based on an active sideband optimization technology for improved picture quality that Nokia developed.

Though Nokia has cut down on the number of TV chassis it manufactures, its managers are still beset by the problems of marketing their technology to a fragmented Europe. Brand names, still numerous, vary from country to country. However, Nokia expects to capitalize on the opportunities created when new technologies leave the laboratory. One, HDTV, may hit Europe ahead of Japan and the United States. When that happens, Nokia executives said, Nokia may just have the chance to give Europe's top two TV producers—Thomson Consumer Electronics SA of France and Philips NV of the Netherlands—a run for their money.

Aside from research into flat-panel displays and high-contrast tubes, the bulk of Nokia's research effort in television goes into HDTV. Nokia is participating with other manufacturers in the Eureka 95 HDTV technology project. So far the group has agreed with the European Commission to use high-definition multiplex analog components (HDMAC) as a standard for HDTV. HDMAC uses a format of 1250 lines, a 50-Hz field rate and interlaced scanning, and a 16:9 aspect ratio. The interim standard agreed upon was D2MAC, a narrowband version suitable for cable television transmission. Nokia, in addition, has been producing HDTV programs with a Finnish television broadcaster.

Its engineers are also working to exploit Nokia's expertise in multimedia technology, which Nokia executives envision as a marriage of computers and the kind of high-quality, low-cost graphics found in TV sets.

INTERNAL EXPANSION. In telecommunications, Nokia has tended to grow its businesses by internal expansion rather than by acquisition. Nokia Telecommunications, which constitutes 12 percent of Nokia's total revenues, supplies telecommunications equipment for public telecom networks (48 percent of its revenues), mobile and cellular telephones (34 percent), and dedicated

private networks (18 percent).

The market for switching systems that form the infrastructure for mobile and ordinary telephone networks, together with sales of mobile telephones, had been growing for the past three years at more than 15 percent a year. However, last year sales of telecommunications switches and central office equipment (excluding mobile radio and telephone handsets) declined 26 percent to 1.8 billion FIM.

The backbone of Nokia's telecommunications business is its DX-200 line of telephone switches. An analog version was introduced in 1979 and a digital switch in 1982. The line is characterized by a hierarchical structure and modular subsystems, which ensure a smooth upgrade path. The latest version, an all-digital DX-200, introduced in 1990, is based on Santa Clara, Calif.-based Intel Corp.'s 80486 microprocessor and handles 100 000 subscriber lines. It is designed to operate at the equivalent of a Class Five public switching station as a parent switch to smaller, 5000-subscriber units.

Executives point to the company's use of standard parts as a cornerstone of its success in telecommunications. From the very start, Nokia engineers based the switch's design on Intel's 88X86 chips and boards.

While many of its competitors must redesign their own proprietary processors that form the heart of their switches every few years, Nokia need only wait for Intel to produce its next-generation chip along with its software and development support. This strategy has allowed Nokia engineers to concentrate on adapting their switch for varying protocols and for different applications as well as for new technologies.

MANY ALLIANCES. In a field crowded with alliances, Nokia has formed its share. Currently it is cooperating with Tandem Computer Inc., Cupertino, Calif., a U.S. maker of fault-tolerant computers, on such applications as intelligent network nodes. It also has agreements with Logica PLC, London, to collaborate on software for similar applications. And it's involved in a consortium with Alcatel NV, Amsterdam, the Netherlands, and AEG Aktiengesellschaft, Frankfurt, Germany, to develop products for the GSM European digital cellular telephony standard.

In addition, Nokia is working with AT&T Co. on GSM chips. Nokia came out with its first GSM components and subsystems last summer and claims a nine-month lead over competitors in developing products for the standard.

The company is also developing features in its switches to make them suitable for so-called personal communications networks, which are currently being marketed in the UK as private telephone networks. Nokia entered this business last summer with an agreement to supply switches and handsets for a new 1800-MHz network being launched this year by the UK's Microtel Communications Ltd.

Mobile telephones, which include cellular phone handsets and pagers as well as mobile radio, contribute about 16 percent to total sales. Climbing about 30 percent a year since 1987 to 2.5 billion FIM in 1991, it has been Nokia's fastest-growing business. Last year it was the only one not to shrink; sales grew 8 percent to 2515 million FIM. Nokia predicts that the 5.5 million mobile telephone handsets sold worldwide in 1991 will balloon to 17 million by 1995.

Nokia's latest cellular portable telephone, the Nokia 101, was launched in January. Weighing only 275 grams, the product is being manufactured to all major analog cellular telephone standards. Its predecessor, the Cityman 100, which sold briskly in Europe, was introduced in the United States in 1990. Its success was attributed to a low price and the larger number of functions it performed over its competitors. With such products, Nokia has established itself as Europe's preeminent cellular telephone supplier. Worldwide it is second only to Motorola Inc., Schaumburg, Ill., with Tokyo's NEC Corp. third.

Nokia consolidated this position early last year when it bought the British mobile phone maker Technophone Ltd., which markets both in Europe and the United States. With the acquisition, Nokia increased its U.S. market share to 15 percent from 10 percent (including 5 percent sold under the label of Tandy Corp., Fort Worth, Texas).

But the main reason for acquiring Technophone, Nokia executives said, was to gain research staff. The acquisition adds 100 engineers in south England to the 300 or so in the mobile phone division in Helsinki. "We cannot grow [our research staff] in Finland any more," said Ollila. "We will have to go to the United States and England to do that."

Executives have made it a priority to spread R&D activities elsewhere in Europe. In the last few years Nokia has opened a 50-person laboratory in Cambridge, England, to do research on transmission and switching. And it is looking for a site in Germany for a broadband communications laboratory.

Currently, Nokia's key research projects cover several areas and include many cooperative efforts. In mobile telephones, R&D is concentrated on digital technology, particularly for Europe's GSM system. Nokia participates in the development of standards and protocols for this technology in the European Telecommunications Standards Institute, near Nice, and the telecom industry association (Ectel) in London. It also has an agreement with Qualcomm Inc., San Diego, Calif., to develop digital telephone technology for the U.S. market.

Nokia has leveraged its R&D investment by participating in joint ventures and in European Community consortia such as Eureka (European Research Cooperation Agency), Esprit (European Strategic Program for Research and Development in Information Technologies), and RACE (Research and Development in Advanced Communications Technologies for Europe). Nonetheless, almost 90 percent of the 3400 research scientists and engineers work out of the company's laboratories in Finland.

WEAKEST LINK. In all its businesses, Nokia executives admitted that Nokia is weakest in marketing and distribution. For its high-volume mobile phones, it is trying to overcome this by forming marketing alliances, such as the one with Tandy Corp. Another is with Nippon Idou Tsushin Corp., a Japanese cellular telephone system operator, whereby the two will develop and market a digital cellular phone when Nippon begins operating its digital network in Japan in 1993.

The need for marketing expertise is growing even in such staid businesses as telecommunications switches. If the trend toward liberalization in European telecommunications continues, Nokia sales people will be chasing more and more private firms in addition to the big domestic carriers. But, Nokia executives said they preferred to have their R&D firmly in place, which it is, and need to work on their marketing, rather than the other way around. ◆

Nokia in Russia and the new republics

Finland's position on Russia's northwestern border and its longstanding trade links with Russia are potentially one of Nokia Corp.'s biggest strengths. Since 1948 Nokia had benefited from a special trade relationship between Finland and the former Soviet Union whereby most trading was done through barter, with the books balanced every five years or so.

Nokia's sales in 1990 to the Soviet Union amounted to 1.3 billion Finnish markkas (FIM). Most involved low-tech wares. One joint venture, for example, manufactured 8-mm copper wire, some of which Nokia shipped to Finland and elsewhere in Europe.

But all barter was discontinued at the end of 1990, when the Soviet Union allowed only hard currency trade. As a result, Soviet-Finnish trade in 1991 was cut drastically. Nokia's sales almost vanished, falling 1.2 billion FIM from the year before. Though less than 7 percent of Nokia's total revenues in 1990, Soviet trade had been shifting to the more profitable switches for mobile and ordinary telephone networks.

Great potential also exists for selling sophisticated cable-making machinery of which Nokia is the world's No. 1 manufacturer. A huge need now exists, too, for cable itself in the republics of the former Soviet Union. The problem, of course, is the republics' low hard currency reserves.

Stefan S. Widomski, Nokia's senior vice president for international trade affairs, worries that Nokia's advantage in Russia and the republics may slip in the years to come. For one thing, the Finnish government cannot compete with richer western nations that can afford to grant large credits. Nevertheless, when the economy on Finland's eastern border improves, Nokia's biggest asset may very well be the personal relationships it has cultivated through more than four decades. —*F.G.*

Faults & failures

Three little bits breed a big, bad bug

Between June 10 and July 2 last summer, some 20 million telephone customers lost service for several hours in eight mysterious incidents of signaling equipment failure. In a few incidents, fast-acting telephone company employees contained the outages; in most, however, a domino effect spread outages over populous areas in northern California, southern California, the Washington-Baltimore region, and western Pennsylvania.

Now, after a six-month investigation, the cause and contributing circumstances of the outages are clear. Common to all of them was a software failure: one line of code among thousands in signal transfer point (STP) software contained a flaw involving only 3 bits. "What should have been a binary D (1101) was instead a binary 6 (0110); in 3 bits of the character, 1s and 0s had been transposed," *IEEE Spectrum* was told by Harold Daugherty, manager of technology planning at Bell Atlantic in Arlington, Va. Bell Atlantic was one of the companies participating in the investigation, which was led by Bellcore, Livingston, N.J. Others that were also involved in the inquiry were Pacific Bell, DSC Communications, AT&T, and Northern Telecom.

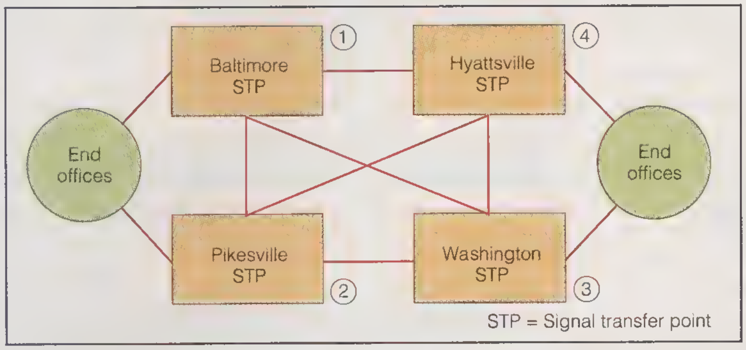
The STPs that were investigated are packet switches that route network control information. They are a key element in Signaling System 7, the internationally accepted protocol that searches for the best route under current traffic conditions. The protocol handles dial-800 toll-free calls, credit-card calls, and caller identification, as well as a host of other new services.

Though the software error was small, it was enough to disable the STPs' overload protection. Instead of discarding accumulated signaling messages when its storage buffers became full, an STP simply shut itself down. Signaling messages meant for it, then, were routed to its "mate," an alternative STP, which itself became overloaded. That alternative unit, because of the 3-bit bug, shut itself down as well. In turn, the second alternative STP became overloaded and shut down.

Gradually, voice connections became deprived of the signaling connections they needed to set up calls and terminate them. When that happened, customers could not call within their region, except to phones that happened to be connected to the same central office.

The outages occurred only in STPs to which a software patch had been added during May and early June—all of Bell Atlantic's STPs and half of Pacific Bell's. Intended to solve a problem that sometimes prevented STPs from acknowledging test messages sent to them, the patch, unfortunately, with its hidden 3-bit bug, introduced a far more serious problem.

Although the STPs' manufacturer, DSC Communications Corp., Dallas, had tested the new code, it had not done so exhaustively. The error became apparent only in service, under certain conditions: when heavy (but not excessive) voice traffic generated a high signaling load for STPs and a trigger mechanism caused signaling messages to accumulate.



Bell Atlantic's Baltimore STP shut itself down and transferred its load to its mate at Pikesville, which followed suit, as did the Washington STP and its mate at Hyattsville. All contained the same 3-bit error.

In one outage, for example, the trigger was a hardware fault in a circuit board in Bell Atlantic's Baltimore STP [see figure]. The STP automatically took some other components out of service to isolate the fault, and congestion and shutdown ensued. That incident, on June 26, disrupted telephone service for 5 million to 6 million customers for 6 hours in the nation's capital, Maryland, Virginia, and parts of West Virginia.

In another outage 2 hours later on the other side of the continent, an error in routing data in Pacific Bell's Los Angeles STP was the trigger. While the corrected data was being loaded, signaling messages accumulated and the 3-bit bug went to work, causing 3 million customers in Los Angeles and parts of Orange, Ventura, and San Diego counties to lose their service for several hours.

The outages lasted so long because efforts to restore service were hampered by continued congestion as backlogs of messages continued to clog STP buffers. To lessen the congestion, the telephone companies had to cut off all traffic to the affected STPs. Thus isolated, those STPs could be brought back into the network one at a time. As long as a congested STP's mate was not subjected to another trigger and was not congested, it could assume the full load temporarily.

At first, the cause was not apparent. In fact, no one knew whether the outages had a common source. Some even suggested that a computer hacker might have infiltrated the signaling network. A common concern was that malfunctions in one company might infect other companies and perhaps spread nationwide. The U.S. House of Representatives' subcommittee on telecommunications demanded testimony by industry experts, and the Federal Communications Commission called for a full investigation.

By early July, Pacific Bell engineers had zeroed in on the 3-bit bug in DSC Communications' software. DSC's fix was to add a patch to the STP software that eliminated a 150-ms mandatory wait before buffered signaling messages were discarded; now STPs can discard messages immediately if they are getting into trouble.

The efficacy of the fix became evident on July 5, when several links failed simultaneously in Bell Atlantic territory. The event would almost certainly have triggered widespread STP shutdowns, but the newly patched software prevented them.

The 150-ms holding time was set to achieve Signaling System 7's goal of losing no more than 1 in 10 million messages. DSC engineers later added another patch aimed at minimizing the effects of discarding messages—which contain information on call billing as well as call setup, routing, and teardown; the STPs now discard according to strict priority and only in times of imminent congestion.

Continuing its investigation, Bellcore uncovered aspects of the Signaling System 7 protocol that may actually set the stage for congestion and make recovery more difficult than necessary. Protocol changes are therefore likely. For its part, DSC Communications has tightened quality assurance on new software issues.

COORDINATOR: George F. Watson
CONSULTANTS: John Devaney, High-Rel Laboratories Inc.; Robert Thomas, Rome Laboratory

PRODUCT PROFILES

The PRODUCT PROFILES advertising section provides a distinctive focus on both new and commercially established products and services that offer practical solutions for engineering and scientific professionals in today's fast-paced, rapidly changing high-tech environment.

Employment opportunities

Organizations seeking engineers and scientists describe their various openings in the following advertising section

In order to conform to the Age Discrimination in Employment Act and to discourage age discrimination, IEEE may reject any advertisement containing any of these phrases or similar ones, "recent college grads," "1–4 years maximum experience," "up to 5 years experience," or "10 years maximum experience." IEEE reserves the right to append to any advertisement, without specific notice to the advertiser, "Experience ranges are suggested minimum requirements, not maximums." IEEE assumes that, since advertisers have been notified of this policy in advance, they agree that any experience requirements, whether stated as ranges or otherwise, will be construed by the reader as minimum requirements only. While IEEE does not ban the use of the term "entry level," its use is discouraged since, to some, it connotes an age rather than an experience designation. IEEE accepts employment advertising to apprise its members of opportunities. Interested parties should be aware that the political and humanistic values of certain advertisers may differ from their own. IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

CLASSIFIED

ADVERTISING RATES

DISPLAY ADVERTISING RATES—call Theresa Fitzpatrick at 212-705-7579

CLASSIFIED

Positions open—$36.00 per line, not agency-commissionable

Positions wanted—$36.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy

All classified advertising copy must be received by the 25th of month, two months preceding date of issue. No telephone orders accepted. For further information contact Francesca Silvestri, 212-705-7578.

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

Academic Positions Open

Princeton University: the department of Electrical Engineering invites applications for full time, tenure-track faculty position. The disciplines of particular interest are complex systems, specializing in areas such as robotics, manufacturing systems, networks, and stochastic or nonlinear systems; and signal processing, specializing in areas such as video and image processing. Please send a complete resume, a description of research and teaching interests, and names of three references to Professor Stuart Schwartz, Chair, Dept. of EE, Princeton University, Princeton, NJ 08544-5263. Princeton University is an equal opportunity/affirmative action employer.

Research Position—University of Southern California. Interested candidates are encouraged to apply for a post-doctoral research position. Research activities are in gas-phase pulsed power switches, electron beam sources, and solid state devices for pulsed power. Please send a resume and the names of 3 references to Dr. Martin Gundersen, SSC-420, University of Southern California, Los Angeles, CA 90089-0484.

Research Assistant Professor: The University of Pittsburgh, a major heart transplantation center, is committed to develop non-invasive techniques for early detection of rejection and coronary occlusive disease. The position requires experience in intracardiac, surface electrocardiogram, and ultrasound characterization of tissues. A Ph.D. in electrical engineering or a related field is required. Understanding of the rejection process, development of coronary occlusive disease in transplant patient, and the capability to contribute innovative ideas and solutions is a plus. It is required that the candidate has knowledge of system identification, signal processing techniques, UNIX, and data acquisition techniques. Capability to make specific instruments like 15-lead and high frequency digital ECG is a must. Experience with SUN and NeXT workstations is desirable. Major component of work involves data acquisition and analysis. Salary ranges from $36,000 to $42,000 commensurate with qualifications. Applicants should have experience working and interacting in an environment with large number of transplant patients. Send resume to Dr. P.S. Reddy, 3492 Presbyterian University Hospital, De Soto & O'Hara Streets, Pittsburgh, PA 15213. An Equal Opportunity Employer.

Stanford University—Department of Electrical Engineering. Tenured or Tenure-Track Appointment in Telecommunications. Stanford University seeks applicants for a tenured or tenure-track appointment in Electrical Engineering in the field of telecommunications. A Ph.D., a demonstrated ability for independent research and a strong interest in graduate and undergraduate teaching are required. Candidates should have a record of innovative publications, and industrial experience will be regarded favorably. The appointee will be a member of the Center for Telecommunications at Stanford. This Center involves about 15 faculty members from the Departments Electrical Engineering, Computer Science and Engineering Economic Systems and approximately 10 industrial firms from around the world. A central theme of the Center is personal communications, interpreted in a broad sense. Some areas of particular interest include wireless access to networks, RF technology for portable communications, and protocols for personal communication networks. However, other areas in telecommunications are also of interest. Stanford University is an Equal Opportunity Employer and encourages applications from women and minority candidates. The deadline for receipt of applications is July 31, 1992. Please submit a detailed resume, a publication list and the names of five references to Prof. Joseph W. Goodman, Chairman, Department of Electrical Engineering, McCullough 152, Stanford University, Stanford, CA 94305-4055.

University of California, San Francisco—Director, Radiological Informatics. The Department of Radiology at the University of California, San Francisco, is searching for a Director for the newly created Section of Radiological Informatics. The Director of Radiological Informatics will lead a group of computer scientists and other professionals to provide both research and clinical service in Picture Archiving and Communication Systems (PACS), Radiology Information Systems (RIS), Office Automation, Computer-Assisted Instruction (CAI) with digital imaging, expert system applications, image processing, and speech-recognition applications. These activities will focus on software design and implementation, but some hardware fabrication on the board level will also be anticipated. A new Imaging Laboratory, which will be the primary site for this team, will begin construction shortly. The Director will be appointed at the level of Associate Professor or Professor of Radiology in Residence (depending on qualifications) and will also serve as Vice-Chairman and a member of the Executive Committee of the Department of Radiology at UCSF. The Director should have a Ph.D. degree in a related field, several years of experience in a related position, an established track record in terms of publications and peer reviewed funding, experience in teaching postdoctoral students, and demonstrated leadership of a research group in Radiological Informatics. The University of California, San Francisco is an Equal Opportunity/Affirmative Action Employer. Minority groups, women and handicapped individuals are encouraged to apply. Send CV to: Charles A. Gooding, M.D., Chair, Search Committee, UCSF, Department of Radiology, San Francisco, CA 94143-0628.

Assistant Professor, Electrical Engineering. Applications are invited for a tenure-track position at the Assistant Professor level in Electrical Engineering. The successful candidate must be dedicated to teaching at the undergraduate and graduate levels and have demonstrated their ability to conduct high-quality research in their chosen field. Preference will be given to candidates with a background in one of the following areas: computer engineering, controls, VLSI or high-speed electronics. The successful candidate must have completed the requirements for a Ph.D. in Electrical or Computer Engineering prior to appointment. Review of applications will begin immediately and continue until the position is filled. Send your application with the names of three references to: Dr. Gabriel Lengyel, Search Committee Chair, Position # 081027, The University of Rhode Island, P.O. Box G, Kingston, RI 02881. An Affirmative Action/Equal Opportunity Employer.

The Department of Electrical Engineering at The University of Maryland Baltimore County (UMBC) has an opening for an experimentalist at the level of Research Associate to perform research in a well equipped laboratory in the area of fiber optics including: fiber sensors, fiber lasers, solid state and semiconductor lasers, and Photonic Networks. Ph.D. in EE or Physics and related experience required. Send a detailed resume along with the names of three references to: Gary M. Carter, Associate Professor, Department of Electrical Engineering, UMBC, Baltimore, MD 21228. UMBC is an Affirmative Action/Equal Opportunity Employer.

The Department of Electrical Engineering, University of Maryland Baltimore County Campus (UMBC) is currently emphasizing the research area of communications and signal processing, and the area of photonics. We anticipate significant growth in the faculty over the next five years in support of our communications and signal processing component. Our emphasis in the immediate future will be on expanding the research activities and increasing university/industry/government cooperation in this area. We are currently seeking candidates to fill a tenure-track position at the assistant professor level with a specialty and broad interest in signal processing as applied to: speech and image processing, controls, communications, sonar and radar, biomedical systems, remote sensing, or to the implementation of signal processing algorithms. The person we are seeking is expected to: 1) initiate and develop an active, independent funded research program; 2) teach fundamental courses, and develop advanced courses in signal processing theory, algorithms, and/or their software and hardware implementation; 3) perform academic duties, such as student advising and commit-

tee participation associated with our program; and 4) assist in the enhancement of the interactions between this department and industrial and governmental concerns. Applicants should have an earned Ph.D. in electrical engineering, have a strong theoretical background with (preferably) algorithm or hardware design and real-time implementation experience, a demonstrated potential for excellence in research and the ability to teach effectively at both the undergraduate and graduate level. UMBC is located just south of Baltimore City in Maryland and is approximately 40 miles northeast of Washington, D.C. Both the campus and the greater Baltimore region are experiencing substantial growth with exciting and unique opportunities for collaborative research, including strong interactions with the University of Maryland medical and dental schools, and with numerous research and technology organizations in the greater Baltimore and Washington region. The Department of Electrical Engineering at UMBC currently enjoys excellent relationships with local industry and state and federal agencies. The Department of Electrical Engineering was initiated in 1986 and has grown to a full-time faculty of 8 and part-time faculty of 4 with a student body composed of 44 MS students (26 full-time and 18 part-time) and 29 Ph.D. students (23 full-time and 6 part-time), and annual research expenditures of approximately $800K. The new Engineering and Computer Science Department which will open for the Fall Semester of 1992 will supplement our current office and research space in the TRC building. The Department has access to considerable computing resources. The University's primary computing system for research use consists of two clustered VAX 8600 computers running VMS and a VAX 785 running ULTRIX (UNIX). In addition, UMBC is a component of the larger University of Maryland Instructional and Research Computer Network, which provides access to computers at other University of Maryland campuses. From UMBC, users may also communicate with other researchers on a national and International basis via BITNET and ARPANET. The department also has on-line access to the CRAY computers at San Diego and at Livermore. The department and the faculty maintain a number of 386/486 PCs, MACs, and a HP9000 workstation LAN. The applicant should send a curriculum vita and resume, with the names and addresses of at least four references (3 academic and 1 professional) to: SP Search Committee, Electrical Engineering Department, UMBC, 5401 Wilkens Ave., Baltimore, MD 21228-5398. UMBC is an Affirmative Action/Equal Opportunity Employer.

BellSouth Eminent Scholar's Chair in Electrical Engineering. The Department of Electrical Engineering at the University of Florida invites nominations and applications for an endowed, chaired professorship in the general field of telecommunications. The Department of Electrical Engineering is the largest department in the University of Florida with 518 undergraduates and 375 graduate students. The department is ranked 21st of more than 250 Electrical Engineering undergraduate programs. The Electrical Engineering faculty is comprised of fourteen IEEE Fellows, two members of the National Academy of Engineering, one of whom holds an endowed chair in Microelectronics. The College of Engineering is ranked 17th nationally based on its funded research programs. For the BellSouth Chair, we seek a researcher and teacher of great distinction, whose work has been internationally acclaimed. Proceeds from an endowment and additional resources will provide an environment commensurate with the excellence of the person sought. Nominations and applications should be sent to Professor Donald G. Childers, Chairman, BellSouth Chair Search Committee, Department of Electrical Engineering, 405 CSE, University of Florida, Gainesville, FL 32611-2024; telephone (940) 392-2633. The application deadline is August 1, 1992. The University of Florida is an Affirmative Action Employer and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request.

Senior/Research Associate-University of Chicago. A position is available for an experienced scientist with a Ph.D. (or equivalent) degree with

The position of PRESIDENT of the Canadian Microelectronics Corporation offers a unique career opportunity in the area of microelectronics and associated university research. The Canadian Microelectronics Corporation is a non-profit organization holding a major Grant from the Natural Sciences and Engineering Research Council. It has a membership of 28 universities, as well as 17 related industries and individuals. It is the centre of a National Design Network supporting world class research and development in microelectronics in Canadian universities. Its challenge is to support effectively its member universities in meeting the increasing demand for more capable graduates for the industries that develop and apply microelectronics technology. Through a competitive loan program, CMC provides Canadian universities with specialized equipment and state-of-the-art software for research purposes. It maintains sophisticated communication links with its research affiliates and provides advanced support for fabricating integrated circuits. CMC has a staff of 21 permanent employees and an annual budget of approximately $5 million. It is located on the campus of Queen's University in Kingston, Ontario with access to all university facilities.

PRESIDENT

The President is appointed by, and reports to, the Board of Directors and is responsible for directing the general and active management of the affairs of the Corporation.

Specific responsibilities include representation and promotion of the CMC with Canadian universities and industries and liaison with counterparts in other countries at meetings, conferences and workshops. Further responsibilities include preparing business plans and reports, developing policy, planning for the future, and managing the general administration of the CMC. CMC plans to develop broader industrial ties and the President will be responsible for establishing and maintaining a network of industrial contacts and for enhancing overall industrial participation in the corporation. The incumbent will use input gained from the membership at large, from the Technical Advisory Committee and from the Executive Committee of the CMC, as well as from personal interaction with university, industrial and government contacts in Canada and abroad, in making plans and decisions with regard to programs, expenditures and personnel.

This is a very challenging position in a fast-paced, highly computerized environment. The successful candidate will have proven leadership and management skills as evidenced by ten or more years of experience at a senior management level, preferably with a number of those years in an industrial environment. A post-graduate education (preferably Ph.D.) in Electrical Engineering, Computer Science or other related applied science, with a solid understanding of issues related to microelectronics is required. Superior written, verbal and presentation skills are essential. The ability to communicate in both official languages is highly desirable. Preference will be given to a Canadian citizen or landed immigrant.

The position offers a competitively scaled remuneration and benefits package based on qualifications and experience. Moving assistance will be provided. Applications will be treated in confidence. CMC is an equal opportunity employer.

Please submit a resumé to:

Chairman, Search Committee
CANADIAN MICROELECTRONICS CORPORATION
210A Carruthers Hall
Queen's University
Kingston, Ontario K7L 3N6 Canada

a quantitative biology, biophysics, bioengineering or related background. Four to five years of research experience is required. Experience with industrial and pharmaceutical areas preferred. Applicants should have a strong interest in working with research and clinical faculty to develop and foster research programs. This is a full-time position with excellent benefits. No telephone calls please. Send a cover letter with a resume, salary history and list of references to: Raphael C. Lee, M.D., Sc.D., The University of Chicago, Department of Surgery, 5841 S. Maryland Ave., MC6035, Chicago, IL 60637. The University of Chicago is an Affirmative Action/Equal Opportunity Employer.

University of Virginia: The Semiconductor Device Laboratory is seeking applicants for expected openings in GaAs device processing and heterodyne receiver technology. Rank and salary will be commensurate with experience. However, it is expected that the GaAs processing position will be at the Research Scientist level, while the heterodyne receiver position may be at the senior scientist or Research Faculty (non-tenure track) level. Qualifications and duties are as follows: 1) GaAs processing: requires a BSEE or equivalent with substantial experience in process technology including sub-micron lithography, dry and wet etching, thin film deposition, mask layout, device evaluation and testing. Experience in process development is very desirable. 2) Heterodyne technology: requires an MS or PhD in EE or a related field. Extensive experience in submillimeter technology, GaAs Schottky mixers and varactors, SIS junctions, local oscillator systems, waveguide and open-structure technology, and cryogenics are also required. Both positions require applicants who are highly motivated and independent, yet able to work effectively in a group. Applicants must be able to make a significant contribution to our research while also being an effective role models for our students. Please send resumes to the following address by June 1st to ensure full consideration: Dr. T.W. Crowe, Dept. of Elec. Engr., Thornton Hall, Univ. of Virginia, Charlottesville, VA 22903. The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

Columbia University—The Department of Electrical Engineering invites applicants for a tenure-track faculty position in signal, image and video processing. A successful candidate is expected to establish a strong research program and have a desire to teach at both the undergraduate and graduate levels. Expertise is sought in theory, algorithms and realization of multimedia systems. Experience with image/video computing architectures would be helpful. The research will be conducted in conjunction with the Image and Advanced Television Laboratory, a state of the art research facility in digital video and multimedia communications. The laboratory is a key component of the Center for Telecommunications Research, a large cross-disciplinary Engineering Research Center, sponsored by the National Science Foundation and industrial participants. Please send your resume and the names of three references to: Professor T.E. Stern, Chairman, Department of Electrical Engineering, Columbia University, 500 West 120th Street, Room 1312, New York, NY 10027. Columbia is an equal opportunity/affirmative action employer.

University of South Florida, Department of Electrical Engineering is accepting applications for tenure track assistant or associate professor positions. Earned PhD required. Resumes will be considered in the following two areas: 1) Compound Semiconductor Materials and Devices. Background and experience in the development of cadmium telluride, copper indium diselenide, etc. for solar cells is desirable. 2) Electric Power Systems. Background in control and conversion of electric power, power delivery and energy management is desirable. Applicants should send resume and the names of three references to Dr. Elias Stefanakos, Chairman, Department of Electrical Engineering, University of South Florida, Tampa, Florida 33620. The University of South Florida is an Equal Opportunity/Affirmative Action Employer.

The Ultimate Challenge

Are you ready for it? Career challenges that stimulate the mind and stretch your creativity. An exciting technology – ultrasound that produces products that can help save lives. A dynamic environment where innovation and responsibility are standards. Sound like the ultimate challenge? It is. It's Acuson. No exaggeration!

IMAGE ANALYSIS MANAGER/ENGINEERS

Working with a group of highly specialized professionals in ultrasound imaging, you will assess and optimize overall ultrasound imaging system performance in a variety of medical applications. A thorough theoretical and practical understanding of factors affecting ultrasound imaging systems is essential, as is the ability to work on all phases of a project from concept architecture to system verification. Manager will also have responsibility for technical project leadership, resource and career planning, training, tool and process development and new product definition. All positions require an MS or PhD in Physics, EE or Biomedical Engineering and solid experimental and analytical skills. In addition, Managers must have prior technical project leadership expertise coupled with 5+ years of experience. Engineering openings require 2-5+ years of experience. (Both senior and entry level opportunities are available.) Position Code: CC/1792

ACOUSTICS ENGINEER

Use your related background and independent work style to excel as you design medical ultrasound transducers. Challenges will include developing experimental characterization methods for materials used in transducers, specifying acoustic parameters, and developing necessary analytical numerical/experimental tools to help model existing and future transducers. You'll also lead the acoustical aspect of transducer design projects. Leading candidate will have an MS plus 3 years of experience or a PhD. A thorough understanding of elastic/acoustic waves, wave propagation and piezoelectricity is required. An understanding of electrical circuits, network theory and transmission lines is important, as are strong analytical skills and hands-on experience with basic acoustical/electrical measurement techniques. The ability to design experiments, study independently and interface with individuals from all disciplines are key. Position Code: CC/1892

ELECTRICAL-MECHANICAL PACKAGING ENGINEER

Apply your BSME and 6+ years' experience to develop and analyze co-axial cable components and termination methods. You must have demonstrated experience with electrical testing and performance evaluation, mechanical reliability testing and evaluation, cable assembly design and manufacturing, RFI/EMI shielding, interconnection methods, and failure analysis. The ability to work with cross functional teams and vendors as well as on an individual contributor basis is essential. Position Code: CC/1992

Experience the ultimate challenge. We offer an excellent compensation program, including stock options. Please send your resume, indicating position code on envelope, to Acuson, 1220 Charleston Road, P.O. Box 7393, Mountain View, CA 94039-7393. EOE

acuson

COMPUTED SONOGRAPHY

Quality design and advanced technology. Because lives depend on it.

Siemens Pacesetter, Inc. makes implantable cardiac devices. Tiny enough to fit in your fist. Powerful enough to sustain life. Innovative enough to have made history. Incredible enough to last a decade or more. Perceptive enough to know when patients are exercising and when they're resting.

But at Siemens Pacesetter, Inc., together with our multi-billion dollar parent company Siemens, we are looking toward the future. We are developing implantable devices that can start a stopped heart. Pacemakers tiny enough to be implanted in premature babies with heart defects. Implantable technology that mimic the human heart down to the subtlest nuances.

The field of cardiac device therapy has come so far so fast, there's no telling where technology will take us in twenty years. If you need incredible challenges in a high-tech environment and the opportunity to do work that literally saves and changes lives, you'll find your opportunity to make a difference at Siemens Pacesetter, Inc. Future opportunities include:

AUTOMATIC TEST ENGINEER

To perform analog and digital circuit design, SW development and test system integration. Requires BSEE and 3+ years ATE experience in the design/development of computer-based automatic production test equipment. **Respond to Dept. IEEE/ATE.**

IC LAYOUT DESIGNER

Utilizing Sun SPARC workstations, will layout CMOS analog/digital circuits with standard cell and fully customized methodologies. Requires 2+ years layout experience and working knowledge of UNIX. **Respond to Dept. IEEE/ICDE.**

PROCESS ENGINEER

Will handle machine design projects utilizing electro-pneumatic mechanisms/processes involving YAG laser welding. Requires BSME/EE with 5 years experience in CNC machine control, diagnostics, mechanical fixture design and repair of digital/analog circuits. **Respond to Dept. IEEE/PE.**

SR. PROCESS ENGINEER

Will develop/implement new processes, equipment, components and manufacturing methods to support hybrid test and manufacturing. Emphasis will be on improving manufacturing yields, designing SPC systems and conducting hybrid material R&D. Requires BSEE/ME; 5 years hybrid experience preferred. **Respond to Dept. IEEE/SPE.**

SOFTWARE QUALITY ENGINEER

Will develop/implement software test designs for validation/verification of product and manufacturing. Requires experience in software development for microprocessor-based products and software test design procedures. A BSCS or equivalent is desirable. **Respond to Dept. IEEE/SQE.**

SR. COMPONENT RELIABILITY ENGINEER

Requires BSEE with 5 years experience in reliability engineering, failure analysis techniques and rate predictions. Knowledge of IC and hybrid design/evaluation/qualification techniques and CMOS is essential. **Respond to Dept. IEEE/CRE.**

SR. ANALOG ELECTRONICS DESIGN ENGINEER

Duties include designing low power CMOS op amps and switched capacitor circuits and overseeing layout. Will also perform some system design, integration and scheduling. Requires BS/MS in Electronics, 10+ years analog design experience and 5+ years IC design experience. Thorough knowledge of SPICE and FET models a must. **Respond to Dept. IEEE/AEDE.**

SR. ELECTRONIC PRODUCT ENGINEER

BSEE and 3-5 years experience in analog/digital design, CMOS/TTL devices and microprocessor-based systems essential. Ideal candidate will have knowledge of hybrid micro-electronics involved in the manufacture of high-reliability electronic devices. **Respond to Dept. IEEE/EPE.**

SOFTWARE ENGINEER

Utilizing Assembly and C languages, will design/develop system and application SW for real-time embedded microprocessor-based device support products. Requires BSEE/CE or equivalent and 3+ years experience in embedded microprocessor and system-level SW design/development. **Respond to Dept. IEEE/SE.**

In addition to our desirable Southern California location, we offer competitive compensation, paid relocation and an excellent benefits package, including employer-contributed pension plan, 401(k), tuition reimbursement, vision care and a choice of dental/health plans. Send resume (NO PHONE CALLS, PLEASE!) to the appropriate department: **Greer A. Brooks, Employment Representative, Siemens Pacesetter, Inc., 15900 Valley View Court, P.O. Box 9221, Sylmar, CA 91392-9221.** AA/EOE

Siemens Pacesetter®

Excellence in Cardiac Pacing

Recent books

(Continued from p. 12F-E)

land, Joseph F., and *McPartland, Brian*, McGraw-Hill, New York, 1991, 168 pp., $14.95.

Robot Motion Planning. *Latombe, Jean-Claude*, Kluwer Academic Publishers, Dordrecht, the Netherlands, 1990, 651 pp., $95.

Running Microsoft Word 5.5. *Rinearson, Peter*, Microsoft Press, La Vergne, Tenn., 1991, 686 pp., $24.95.

Telecommunications: The Transmission of Information. *Dayton, Robert L.*, McGraw-Hill, New York, 1991, 184 pp., $35.95.

Analog Integrated Circuits for Communication. *Pederson, Donald O.*, and *Mayaram, Kartikeya*, Kluwer Academic Publishers, Dordrecht, the Netherlands, 1990, 568 pp., $95.

Structural Analysis in Microelectronic and Fiber-Optic Systems, Vol. I. *Surhi, Ephraim*, Van Nostrand Reinhold, New York, 1991, 417 pp., $69.95.

Optoelectronics for Environmental Science. *Martellucci, S.*, and *Chester, A.N.*, Plenum Press, New York, 1991, 293 pp., $79.50.

The Verilog Hardware Description Language. *Thomas, Donald E.*, and *Moorby, Philip*, Kluwer Academic Publishers, Dordrecht, the Netherlands, 1990, 223 pp., $55.

Inside Autocad, 6th edition. *Raker, D.*, and *Rice, H.*, New Riders Publishing, Gresham, Ore., 1990, 896 pp., $34.95.

POSIX Programmer's Guide. *Lewine, Donald*, O'Reilly & Associates Inc., Sebastopol, Calif., 1991, 550 pp., $34.95.

Synchronization Design for Digital Systems. *Meng, Teresa H.*, Kluwer Academic Publishers, Dordrecht, the Netherlands, 1990, 175 pp., $59.95.

Design & Build Electronic Power Supplies. *Gottlieb, Irving M.*, Tab Books, Blue Ridge Summit, Pa., 1991, 163 pp., $17.95.

Freehand Graphics. *Sutherland, Martha*, Design Press, New York, 1991, 160 pp., $14.95.

Norton Utilities 5.0. *Evans, Richard*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 343 pp., $16.95.

Microwave Oven Repair, 2nd edition. *Davidson, Homer L.*, Tab Books, Blue Ridge Summit, Pa., 1991, 370 pp., $19.95.

Quantum Semiconductor Structures. *Weisbuch, Claude*, and *Vinter, Borge*, Academic Press, San Diego, Calif., 1991, 252 pp., $34.95.

Upgrade Your IBM Compatible and Save a Bundle. *Pilgrim, Aubrey*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 245 pp., $19.95.

Computerization and Controversy. *Dunlop, Charles*, and *Kling, Rob*, Academic Press, San Diego, Calif., 1991, 755 pp., $39.95.

The Philosophy of the Grammarians. *Coward, Harold G.*, and *Raja, K. Kungunni*, Princeton University Press, Lawrenceville, N.J., 1991, 609 pp., $65.

Lotus 1-2-3: The Master Reference. *Stark, Robin*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 582 pp., $24.95.

Practical Reliability Engineering, 3rd edition. *O'Connor, Patrick D.T.*, John Wiley & Sons, Somerset, N.J., 1991, 409 pp., $64.95.

Microsoft Excel. *Microsoft*, Microsoft Press, La Vergne, Tenn., 1991, 271 pp., $34.95.

Help Design The Systems Of Our Future

ABB Power T&D Company Inc., part of the world's largest electrical engineering firm, seeks the following software systems professionals for outstanding opportunities at its Raleigh, NC location.

Lead Software Developer

We are seeking an individual with SCADA and real-time programming experience to act as Technical Designer and Project Leader on a full range of real-time software projects, from design through acceptance testing. To qualify, applicants should have at least 10 years' background in developing Electric Power Systems SCADA, including an understanding of SCADA/EMS communications protocols, experience with UNIX applications in a multi-process/multi-user environment, as well as a background in designing/implementing C and FORTRAN applications using a relational database. An MSEE or equivalent is preferred.

Electrical Power Systems Engineer

The selected candidate will have 10 or more years' experience in the Electric Power Systems Industry (distribution experience is preferred), which includes developing and applying power system algorithms. Recent experience in C, UNIX, X-Windows, Motif and SQL Relational Databases is preferred. An MSEE is required; knowledge of optimization techniques/algorithms and on-line control applications is a plus.

Both positions require proof of U.S. residency.

We are an equal opportunity employer offering a competitive salary and benefits program. For consideration, please send your resume, indicating positions of interest, salary history/requirements, and availability to:

ABB Power T&D Company Inc.
Automated Distribution
Att: T.W. Reeher

P.O. Box 9533
Raleigh, NC 27611

ABB
ASEA BROWN BOVERI

I/C DESIGNERS

HYPRES, Inc. is a world leader in commercial and experimental superconducting technology. Our success has created several openings for candidates with strong records of innovation and the ability to develop unique approaches, solutions and inventions that will advance the performance of high sensitivity and high speed devices and systems.

A Ph.D or equivalent experience in GHz or above, I/C, Hybrid or Bi-Polar Analog Design required. Your challenges will include the development of new circuit architecture and design approaches, culminating in the design of complex Josephson junction circuitry for products.

In return for your valued contributions, HYPRES offers an exciting research-driven environment, attractive salaries and benefits including relocation assistance. For confidential consideration, please send your detailed resume to: **Hollis L. Caswell, Chairman and CEO, HYPRES, Inc., 175 Clearbrook Road, Elmsford, NY 10523.** We are an equal opportunity/affirmative action employer.

HYPRES, Inc.
Making Superconducting Electronics A Reality.

MANAGER

A major corporation is seeking executives to manage a large technical operation for a midwest facility. A challenging employee-oriented and high-tech environment is provided. The successful candidate must possess good interpersonal skills, have demonstrated leadership ability and willingness to assume responsibility.

MANAGER, ELECTRONIC ENGINEERING - Manages development and engineering production activities for a wide range of products, including hybrid microcircuits, printed wiring boards, digital programmers, sequencers, and trajectory sensing signal generators.

Qualifications:

- Several years experience in managing technical development and production of electrical products
- BSEE and thorough knowledge of engineering principles involving electrical subassemblies, including circuit theory, test, design and system performance
- Advanced degree in Electrical Engineering preferred.

MANAGER, RADAR OPERATIONS - Manages production and quality operations for microwave devices, including designing, developing and producing radar products.

Qualifications:

- Several years experience in managing related functions
- BSEE and thorough knowledge of microwave engineering
- Advanced degree in Electrical Engineering and M.B.A preferred

Selected candidates can expect a competitve salary, comprehensive benefits and opportunity for professional growth. Send your resume with salary history in confidence to:

IEEE Spectrum, Box 5-5
345 East 47th St., New York, NY 10017

An Equal Opportunity Employer M/F/H/V

Magnavox, a leader in satellite communication and navigation systems, has an immediate opening for a:

DIRECTOR, SYSTEMS ENGINEERING

We are looking for a very senior BSEE with at least 10 years experience, demonstrated technical expertise and solid management skills. You will be responsible for the organization and direction of our Systems Engineering and Systems Integration and Test Departments.

We need you to have experience in communication systems, digital signal processing, digital modems and related fields. We also require strong background in Military Systems, Cost and Schedule (CAM), design allocation and design validation management.

We offer excellent salaries, comprehensive benefits and the opportunity to be part of an exciting, fast-paced technology team. For consideration, send your resume to: **MAGNAVOX EMPLOYMENT, Dept. 916M, 2829 Maricopa St., Torrance, CA 90503.** U.S. Citizenship Required. Equal Opportunity Employer. PRINCIPALS ONLY, PLEASE!

Magnavox
GOVERNMENT AND INDUSTRIAL ELECTRONICS COMPANY
WEST COAST OPERATIONS

CLASSIFIED

Columbia University. The Department of Electrical Engineering invites applicants for a tenure-track faculty position. Exceptional candidates are sought to fill a potential position in software for telecommunications. A successful candidate is expected to establish a strong research program and have a desire to teach at both the undergraduate and graduate levels. Applicants should have expertise in areas such as object oriented operating systems and databases, data and knowledge engineering, or parallel and distributed systems, with a view toward applications in network management and control or high speed protocols. Research would be conducted within the laboratories of the Center for Telecommunications Research (CTR) a national Engineering Research Center. The CTR is a leading edge interdisciplinary research facility emphasizing network management and control, high speed optical networks, and broadband applications such as multimedia communication and HDTV. Please send your resume and the names of three references to: Professor T.E. Stern, Chairman, Department of Electrical Engineering, Columbia University, 500 West 120th Street, Room 1312, New York, NY 10027. Columbia is an equal opportunity/affirmative action employer.

Cornell University—Faculty Position. The School of Electrical Engineering at Cornell University has one opening in the area of computer engineering. Applications are invited at all levels; however, we are especially interested in applications at the senior level. Applicants should have strong commitments to and outstanding achievements in research and teaching. The research areas of the applicant may include one or more of the following topics: processor and system architectures; distributed and parallel processing; fault tolerant computing; design methodology; computer imaging and vision; scientific computation and applications; design of VLSI systems. Interested persons should submit a letter of application, professional resume, and the names of at least four references to: Director, School of Electrical Engineering, Phillips Hall, Cornell University, Ithaca, NY 14853-5401. Cornell University is an Affirmative Action/Equal Opportunity Employer.

Positions Open—The Department of Materials Science and Engineering at Cornell University invites applications for two faculty positions in materials science and engineering. Senior Faculty Position—This position will become available January 1st, 1993. An ability to develop an exceptional teaching and research program is required. We have a strong preference for candidates with research interests in electronic materials, but distinguished candidates in all fields of materials science will be considered. If interested, please send a brief one page letter outlining your research and teaching interests before June 30th, 1992 to: Chairperson, Senior Faculty Search Committee, Materials Science and Engineering, 214 Bard Hall, Cornell University, Ithaca, NY 14853-1501. Tenure-track Junior Faculty Position -This position is subject to funding availability. Applicants should have a deep commitment to teaching and a strong record of research in one of the following areas: ceramics, electronic materials, metals, or optical materials. It is desirable that the research effort of the candidate benefits from the current experimental capabilities within the department, which include extensive electron microscopy facilities. Candidates should send a curriculum vitae along with a one page statement outlining research and teaching plans before June 30th, 1992 to: Chairperson, Junior Faculty Search Committee, Materials Science and Engineering, 214 Bard Hall, Cornell University, Ithaca, NY 14853-1501. Cornell University is an Affirmative Action/Equal Opportunity Employer and Educator.

The Department of Physics/Electronics Engineering at the University of Scranton anticipates having a tenure track opening at the assistant professor level. Successful candidates will have a doctorate in either electronic (or electrical) engineering or in physics with a strong electronics background. Duties consist primarily of undergraduate teaching. Salary and starting rank are dependent upon background and experience. Some released time from teaching to maintain an active research program is routine and strongly encouraged. Send resume plus the names, addresses, and phone numbers of three references to: Dr. Joseph W. Connolly, Chairman, Department of Physics/Electronics Engineering, University of Scranton, Scranton, PA 18510. University of Scranton, a Jesuit institution in Northeastern Pennsylvania, is an affirmative action/equal opportunity employer.

Rensselaer Polytechnic Institute is soliciting applications and nominations for a newly endowed Roberts' Chair in Solid State Electronics. The endowed Chair is a commitment from Rensselaer alumnus and co-founder of Fairchild Semiconductor, C. Sheldon Roberts, and his wife, Pat. The Chairholder should be internationally known and be capable of providing scientific and technological leadership in microelectronics. Research emphasis can include semiconductor and packaging materials and processing, solid state devices, electronic/photonic systems, modeling and characterization. The Chairholder must qualify as a Professor in the Electrical, Computer and Systems Engineering (ECSE) Department and be a strong contributor to the interdisciplinary Center for Integrated Electronics (CIE) at Rensselaer. The ECSE Department has over 40 faculty members with major strengths in the areas of Solid State/Integrated Electronics, Automatic Controls/Robotics, Communications and Information Processing, Computer Engineering and Fusion Plasmas. The CIE has a broad based research focus in interconnections and interfaces, including silicon and compound semiconductor devices and interfaces, multilevel metallization and interlayer dielectrics, thin-film packaging and high performance digital and analog design. Both the ECSE Department and the CIE are major components of a Rensselaer strategic focus in the area of Manufacturing, Materials and Design. Applications, nominations and inquiries should be addressed to Prof. Ronald J. Gutmann, Director of the CIE and Professor of ECSE, Rensselaer Polytechnic Institute, Troy, New York 12180-3590 or by electronic mail to rgutmann@unix.cie.rpi.edu. Rensselaer is an affirmative action/equal opportunity employer.

Sultan Qaboos University-College of Engineering. Sultan Qaboos University, the National University of the Sultanate of Oman, is seeking applicants for Faculty position in their Electrical and Electronic Engineering, in the following areas: Digital Electronics, Microprocessors, Computer Architecture and Organization, Computer Communication Networks. Candidates must hold an earned Ph.D. degree and must have potential for high quality teaching and the initiation of research work. Rank and salary will commensurate with qualifications and experience. Benefits include free furnished accommodation, free medical service, yearly repatriation tickets and two months paid leave. Interested applicants should submit their C.V. with supporting documents to: The Personnel Affairs Officer, Sultan Qaboos University, P.O. Box 32500, Al-Khod, Sultanate of Oman.

University of Thessaloniki Greece. The newly established department of Informatics (Computer Science), is seeking expression of interest for a series of faculty positions at all levels soon to be announced. All specializations, PhD and Greek citizenship required. Please write to: Prof. J.A. Tsoukalas, Department of Informatics, 54006 Thessaloniki, Greece. Tel: +30-31-991456. Fax: +30-31-909839.

The Hong Kong University of Science and Technology, Dept. of Electrical & Electronic Engineering, invites applications for the Ph.D. programme. The EEE Dept. has excellent research facilities in areas of CAD for VLSI circuits, microelectronics, digital electronics, signal processing and communications. Financial aid in the form of TA/RA and fellowships are available. Send your inquiry to Dr. Kwan F. Cheung, EEE Dept., H.K. Univ. of Science & Technology, Clear Water Bay, Kowloon, Hong Kong.

Hong Kong Polytechnic—Head of Department of Electronic Engineering (tenable immediately). The Hong Kong Polytechnic was established in 1972. With a full-time equivalent student population of 13,500 and a full-time academic staff establishment of around 1,000, it is the largest of the higher education institutions in Hong Kong, offers a wide range of advanced courses and pursues research to doctorate level. The Department of Electronic Engineering offers a part-time MSc Degree course in Electronic Engineering and a BEng (Hons) Degree course on a sandwich or full-time as well as part-time basis. In addition, the Department also offers a range of postgraduate and higher diploma/higher certificate programmes. The Department has close links with local industry and these are reflected in a range of consultancies. Research is being vigorously pursued. Currently, it has approximately 28 MPhil/PhD research students, 40 part-time MSc students, 460 full-time students and 400 part-time students. In 1991/92, the Department has an academic establishment of 47, and enjoys strong technical and administrative support. The Head of Department will be expected to provide leadership to this team in all aspects of academic activities including teaching, research and consultancy. Qualifications and Experience: Candidates should have high academic qualifications at doctoral level and appropriate professional qualifications, together with a proven record of research activities and publications. Relevant experience in industry and the profession will be distinct additional advantages. Candidates will also be required to demonstrate the personal qualities necessary to lead and manage a sizeable Department with all its diverse functions. Professorial Title: Consideration will be given to the award of the title of Professor to a suitably qualified appointee. Salary and Conditions of Service: The salary is within a range and not less than HK$657,000 p.a. (US$1 = HK$7.74 approximately as at 24 March 1992). Initial appointments at this level are normally made on a fixed term contract of four years at the end of which a gratuity equal to 25% of salary earned over the whole contract period is payable. Subject to mutual agreement, a further appointment may be offered at the end of the initial contract period, either on the basis of a further gratuity bearing fixed term contract or on superannuable terms. Other benefits include subsidised housing, leave, passages, medical and dental scheme, and children's education allowance. Applications: Application including curriculum vitae and names of three referees should be sent to the General Secretary, Hong Kong Polytechnic, Hung Hom, Kowloon, Hong Kong before May 29th (Fax 852 364 2166). Further information is obtainable from the same office. Candidature may be obtained by nominations. The Polytechnic reserves the right not to fill this post or to fill it by invitation.

Government/Industry Positions Open

Computer Systems Specialist (Medical Imaging Research/Systems Support)—$38,861—$60,070. The Clinical Center of the National Institutes of Health is seeking a senior systems manager/scientific programmer to provide computer systems support for the Radiology and Nuclear Medicine Departments, and to assist with collaborative ventures between the Clinical Center Imaging Science Group, the Division of Computer Research and Technology, the Biomedical Engineering Branch, and the 13 Institutes. This position is part of a new Clinical Center initiative to improve the Clinical Center's in-vivo imaging capabilities in order to better support the Institutes' clinical research needs. The applicant must have experience in scientific programming and some aspects of system management. Familiarity with image (medical or non-medical) analysis or display is desirable. The position combines image analysis research support with systems support of the clinical in-vivo imaging analysis systems. This includes analysis, display, storage and retrieval of images from a wide variety of state of the art imaging systems. The successful applicant will support this work and the related computer infrastructure. U.S. Citizenship required. Send your Application for Federal Employment (SF-171) and Resume to: Mr. Patrick Murphy, NIH,

CLASSIFIED

Bldg. 10, Room 1C-660, 9000 Rockville Pike, Bethesda, MD 20892. EOE.

Engineer, Senior Device. Define, develop, characterize & evaluate the next generatn of sub-micron CMOS processes. Knowldge of semiconductor device theory, solid state physics, CMOS & bipolar process flow. Knowldge of process, device & circuit simulatn including SUPREM, SUPRA, PISCES, MINIMOS & SPICE. Knowldge of device modeling techniques, numerical analysis, computer operation systm, optimizatn algorithm, device characterizatn techniques & TECAP systm operatn. Knowldge of data acquisitn, parameter extraction techniques, S-parameter, high speed device measurements, hot electron effects & reliability physics. Jobsite: Santa Clara, CA. Ph.D. in EE. Entry lvl. Salary $1038.46/wk. 40hrs/wk. Clip ad & submit w/resume to IEEE Spectrum, P.O Box 5-1, 345 E. 47th St., New York, NY 10017, no later than June 1, 1992.

Engineer, Senior Process. Resp. for developng state-of-art 3-D simulator for advancd CMOS & BJT devices, & enhance procss/device simulators. Knowldg of device physics, numerical techniques, TCAD framewk & concepts. Knowldg of 3-D simulators for advanced CMOS & BJT devices & procss/device simulators. Knowldg of advancd numerical algorithms in simulatn progrms PISCES 2 & SUPREM 3 & 4. Knowldg of device simulator developmnt & advancd device structurs such as non-volatil memry. Able to use simulatn tools such as MINIMOS. Able to progrm in Fortran, C, Pascal, & X-windows w/in UNIX, VM/ CMS, & VMS. Jobsite: Santa Clara, CA. Ph.D. or equiv. in Elec. Eng. or equiv. Entry level. Salary: $55,020/yr. 40hrs/wk. Clip ad & submit w/resume to IEEE Spectrum, P.O. Box 5-2, 345 E. 47th St., New York, NY 10017, no later than June 1, 1992.

Engineer, Senior Process. Resp. for developing plasma & wet etch processes includng characterization using statistical designed experiments & implementation of processes into pilot line production. Knowldge of semiconductor device operation & architecture. Knowldge of gas plasmas & etching processes. Knowldge of diffusion processing & deposition of polysilicon & silicon dioxide. Knowldge of ionic contamination in semiconductor processes includng sodium contamination. Knowldge of optical measurement techniques of multiple layer films. Knowldge of measurements of UV reflectivity, SIMS, TEM & I/V measurements. Knowldge of optical characterization of surface & interface states. Knowldge of computer database. Jobsite: Santa Clara, CA. Ph.D in Material Sci. or Physics. Entry Lvl. Salary: $4,500/mo. 40hrs/wk. Clip ad & submit w/resume to IEEE Spectrum, P.O. Box 5-3, 345 E. 47th St., New York, NY 10017, before June 1st, 1992.

Sales Administrator (Trade Regulations Analyst). Sales Administrator (Trade Regulation Analyst) needed to research relevant laws and regulations pertaining to the development, use and marketing of communication equipment produced and sold in the United States. Analyze current regulations as well as proposed regulations which will effect research and development, distribution and potential problem areas for future products. Gather information through intensive reading, personal interviews and correspondence with federal agencies such as the Federal Communications Commission, the Office of Science and Technology Policy and the National Telecommunications and Information Administration. Provide research reports, interpretations and analysis of such information (including recommendations) to offices in America, as well as Japan. Coordinate product availability with the Sales Administration and Order Entry staff. Requires a Bachelors Degree in Legal Studies or Trade and 2 years experience in job offered or 2 years directly related trade, sales and market research experience. Must be able to read, write and speak Japanese in order to communicate and correspond with overseas offices. Forty hour work week. $35,000 per year. Apply at the Texas Employment Commission, Fort Worth, Texas or submit resume to the Texas Employment Commission, TEC Building, Austin, Texas 78778-0001, Job Order No. 6449069. Ad paid by an Equal Employment Opportunity Employer.

R&D design engineer (electronics): Perform R&D on automated non-dispersive infrared gas sensors used in air ventilation monitors/controllers & fire sensors. Design elect. compnts & systems, & investigate new apps. f/infrared tech. Design software f/automation of elect. communictns modules, incl. code radio-frequency remote control. Need Ph.D. in engineering, electronics, or physics and 3 yrs. job exper. or applied research (electronics) exper. Must know C & assembler. $40,661/yr. Job site & Interview: Goleta CA. Send this ad and resume to Job #AM7771, P.O. Box 9560, Sacramento, CA 95823-0560 not later than 6/7/92.

Reliability & Test Engineer for automotive manufacturer to perform Electromagnetic Compatibility testing on vehicle and components to monitor effects of electromagnetic fields & conducted transient signals on-board electronic components & emission of electromagnetic fields & conducted transients by electronic components; work w/release/test engr to devise for component/test operations & make recommendations to assure electromagnetic compatibility of on-board electronic components; use spectrum analyzers, oscilloscopes, signal generators & receivers, lap-top computers to conduct customized vehicle testing; issue reports interpreting test results; determine acceptable electromagnetic compatibility of vehicle & validation plans for timing of preproduction electromagnetic compatibility testing of vehicles. Min Qual: B.S.—Electrical Engr course work incl 3 courses (1 involving lab work) ea in 1) theory & applic of electromagnetic fields & waves, & 2) control systems, taken in an ABET accredited engr program. 6 mo exp—Engr Research Asst/Engr Aide/Engr intern. Exp must include software applic for signal monitoring (2 mo) & setting up electrical test systems w/analysis based on signal output (2 mo). FT w/O—10 hrs O.T. variable; 7:30a-4:30p M-F $36,000/yr w/O.T. 1.5 x base. Resume: Michigan Employment Security Commission, 7310 Woodward, Rm 415, Detroit, MI 48202. Ref#9192 Employer Paid Ad.

Senior Systems Engineer—Description: Conducts research and development of solutions to improve meteor burst communication technology. Duties include: application of new and existing algorithms into computer-based knowledge/prediction model to improve the prediction of meteor burst communications systems performance; develop solutions to improve time synchronization for multiple systems; research and design test bed equipment; develop solutions to improve noise immunity and incorporate features to provide automatic noise calibration; research problems and develop practical applications for current technology; design meteor burst communications systems and liaison with clients on a technical level; research and design antennas for meteor burst systems. Education: Masters of Science in Electronic Engineering or equivalent. Experience: Three years as a Senior Systems Engineer or in Meteor Burst Communications, and one year of applied experience with modeling meteor burst communications systems using computer-based prediction software. Salary: $60,000 per year, exempt position, from 9:00 a.m. to 5:00 p.m. in the Kent, Washington area. Must have proof of legal authority to work in the U.S. Send resume by June 1, 1992 to: Employment Security Department, E&T Division, Job No. 305339-M, P.O. Box 9046, Olympia, Washington 98507-9046.

Senior Computer Scientist—Project team co-leader in meteor burst development. Duties include: integration of protocols to the model and adapting model to Mcintosh computer; assisting in developing a model adaptable to customer's networks; developing a personal computer based trail monitoring system; work with software personnel to develop various programs and data bases for customer needs worldwide (this requires the transference of data collected by MCC systems into customer systems or presentation of such data to the customer in a variety of easily understood and useful reports); developing software for mobil data communication employing advanced ergonomic techniques. Education: Master of Sciences in Computer Science or equivalent. Experience: Three years as Senior Computer Scientist must include three years of scientific computer programming plus one year of applied experience with meteor ionization modeling. Salary: $50,000 per year, exempt position 8:00 am to 5:00 pm in the Kent, Washington area. Must have proof of legal authority to work in the U.S. Send resume by June 1, 1992 to Employment Security Department; E&T Division; Job # 305126, P.O. Box 9046, Olympia, Washington 98507-9046.

Research Associate in investment management research and computer software development. Duties include directing and coordinating with other research scientists, applied mathematicians, and computer scientists, development of stochastic processing neural artwork models for investment management and prediction. Supervise and participate in numerical algorithms design and computer software development based on the above mathematical models. Requirements: Minimum of Ph.D or equivalent in Applied Mathematics/System Science with skill in numerical analysis and the application of mathematical and stochastic theory, experience in computer modelling and simulation of managerial decision making using neural network modelling. At least two years' experience after graduation, one year in related research and one year in computer modelling. At least two published papers in numerical analysis and computer modelling. Knowledge of C++ and Windows required. Job Site/Int: Walnut Creek, CA. Salary: $50,000 per year on the basis of a forty hour work week. Explanation: 1. Skill in numerical analysis is required for designing efficient numerical algorithms for mathematical/stochastic models. 2. Knowledge of mathematical/stochastic theory is required for developing such models for investment management and prediction. This knowledge is applied towards modelling decision making under uncertainty. 3. Neural networks represents new mathematical tools for modelling decision making under uncertainty. It has found many applications in economic forecasting and prediction, a mainstay of Gifford Fong's consulting business. 4. Published papers represents evidence of research ability and experience in the enumerated fields. 5. The software developed in this company are implemented in C++ language, and utilizes a Windows environment. Four of our five research associates are directly involved in software development. Send this ad and your resume to: Job #GB 27253, P.O. Box 9560, Sacramento, CA 95823-0560, no later than May 31, 1992.

Controls Systems Engineer: entails detail system design, implementation & startup of DCS & PLC Systems, field instrumentation and specification in the oil & gas, pulp & paper, & chemical industries. Experience on Honeywell TDC2000 & TDC3000, Taylor Mod 300, Moore MYCRO & LIL, Allen Bradley PLC's 2 & 5, GE 90/70 a must. Requirements are BSc Engineering in Electrical or Electronic Engineering with a minimum of 8 years direct experience in industrial process controls of which 2 years must be with a large engineering consulting firm. Salary $55000/yr, 40 hours/week, 7:00/7:30 am to 4:00/4:30 pm, Mon to Fri, OT as required. Location: Bellingham, WA, must be able to travel. Send resume by May 31, '92 to Employment Security Department, E & T Division, Job # 299712, P.O. Box 9046, Olympia, WA 98507-9046.

Research Assistant Professor, $28,000/yr, 40 hrs/wk. Will perform research on chemical vapor deposition and etching projects using ultrahigh vacuum equipment, Auger electron and mass spectroscopy, FTIR and Raman spectroscopies. Will use various lasers and plasma reactors for etching and material deposition of copper and PLZT films. Ph.D. in Microelectronics or equiv. w/background in chemistry and 3 yrs' exper. in laser induced physical and chemical processing required. Submit resumes: NM Dpt. of Labor, 501 Mountain NE, Albuquerque, NM 87102. CC#1001. JO#334037.

Government/Industry Position Wanted

Math M.S. 25 yrs R&D, pubs guid waves sys seeks 2-4 mo pos Num Meth-coding Fortran/Rocky Mtn Basic have PC486 (303)494-8405.

READER GUIDE TO PRODUCTS AND SERVICES

EMPLOYMENT GUIDE FOR ENGINEERS AND SCIENTISTS

IEEE-United States Activities has published a revised, expanded third edition of the popular *Employment Guide for Engineers and Scientists*. This two-volume set includes practical advice on the job marketplace, the preparation and use of résumés, the use of employment and outplacement agencies, salary and benefit expectations, and career-planning strategies. It contains a directory of companies that employ IEEE members, with contacts where available. Unemployed U.S. nonstudent members may receive a complimentary copy of this publication by writing the IEEE-USA office, 1828 L St., N.W., Suite 1202, Washington, D.C. 20036-5104. Include membership number with request.

For more information, CIRCLE #81 on the Reader Service Card.

Writing and Speaking in the Technology Professions: A Practical Guide

by David F. Beer, University of Texas at Austin

This book delivers concrete advice by foremost experts on how to communicate more effectively in the workplace. Beer includes discussions of a variety of approaches such as: writing clear and effective technical documents, giving oral presentations more confidently, presenting information visually through graphics, holding productive meetings, and becoming an efficient listener.

PARTIAL CONTENTS: Initial Approaches; Writing Your First Drafts; Text and Graphics; Presenting Information Visually; Construction and Organization; Putting Some Documents Together; Manuals and Instructions; Giving Directions That Work; Proposals; Writing to Win the Customer; Revising and Editing; Refining Your Document; Oral Presentations: Speaking Effectively to Groups; Meeting, Disputing, Listening: Working with Others to Get Results.

1992; 278 pp.
Product No. PP02782
ISBN 0-87942-284-X
Member $24.00 (soft cover)
List $29.95 (soft cover)

To order, call 1-800-678-IEEE or 908-981-0060 outside the United States.

IEEE-USA Open Forum

What are the problems in your area right now? Unemployment? Competitiveness of your industry in global markets? Pensions? Here's your chance to hear what IEEE United States Activities (IEEE-USA) is doing about them. More than that, here's your chance to sound off on what you think IEEE-USA should be doing about them.

On Saturday, June 27, IEEE-USA's leaders will visit Anaheim, Calif., and on Saturday, Oct. 24, they will meet in St. Louis, Mo., for open forums with members. Details of these meetings will be announced later.

Enhancing careers and influencing Government policy on behalf of members is the business of IEEE-USA. Come and learn what is already being done, and tell the leaders what more they could do to benefit you!

For advance information on IEEE-USA programs, or any questions about these meetings, write, phone, or fax IEEE-USA, 1828 L St., N.W., Suite 1202, Washington, D.C. 20036-5104; office, 202-785-0017; fax, 202-785-0835.

1991 IEEE U.S. Membership Salary and Fringe Benefit Survey

The only source of current information on the salaries and fringe benefits of electrical engineers in the United States is now more comprehensive and informative than ever before. Explores more than 50 variables affecting salaries and benefits. Shows salary variation by Metropolitan Statistical Areas, traces salaries vs. Consumer Price Index from 1972, and shows frequency distribution of all statistics. Contains more than 75 exhibits. Essential data for engineers, corporate and engineering managers, and personnel and salary administrators.

Product No.	Member	List
UH0185-9	$74.95	$99.95

To order, call 1-800-678-IEEE or 908-981-0060 outside the United States.

PAPERS COMPETITION HIGHLIGHTS NATIONAL STANDARDS WEEK

The Standards Engineering Society and IEEE Standards are holding a competition for papers on the theme "Standards Promote Competitiveness" to highlight that vital link during National Standards Week. This annual event, celebrated during the second week of every October by the standardization community, focuses national attention on the im-

(Continued overleaf)

READER SERVICE (CIRCLE NUMBERS)

1 PRODUCT INFORMATION

1	10	19	28	37	46	55	64	73	82	91	100	109	118	127	136	145	154	163	172
2	11	20	29	38	47	56	65	74	83	92	101	110	119	128	137	146	155	164	173
3	12	21	30	39	48	57	66	75	84	93	102	111	120	129	138	147	156	165	174
4	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139	148	157	166	175
5	14	23	32	41	50	59	68	77	86	95	104	113	122	131	140	149	158	167	176
6	15	24	33	42	51	60	69	78	87	96	105	114	123	132	141	150	159	168	177
7	16	25	34	43	52	61	70	79	88	97	106	115	124	133	142	151	160	169	178
8	17	26	35	44	53	62	71	80	89	98	107	116	125	134	143	152	161	170	179
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180

MEMBERSHIP INFORMATION — *300 Regular* — *301 Student*

Print or Type only
Name ______________________ Title ____________
Company ______________________
Address ______________________
City ______________ State ________ Zip __________
Country ______________ Business Phone ______________
If this represents a change in address, please fill out form on p. 9

3 ADDITIONAL COMMENTS

____

____

I would like: ______________________

DELIVERY: I received this issue ______________ (date).

For faster information, fax this card to 413-637-4343

5

Void after August 1, 1992 *Void overseas September 1, 1992*

READER FEEDBACK (CIRCLE NUMBERS)

2 EDITORIAL MATTER

Article/Item	Comment: Too simple	Comment: Just right	Comment: Too detailed
ASICs testing	01	02	03
Low-voltage ICs	04	05	06
Reclamation of systems	07	08	09
Distributed computing	10	11	12
CCD imager	13	14	15
Profile: Laverick	16	17	18
Profile: Nokia	19	20	21
For the record: lasers	22	23	24
Newslog	25	26	27
EEs' tools & toys	28	29	30
Software reviews	31	32	33
Faults and failures	34	35	36

Did you find this material stimulating or thought-provoking?

Item	Yes	No
Spectral lines	37	38
Forum	39	40
Books	41	42
Reflections	43	44
Technically speaking	45	46

portance of standards to commerce, industry, and government.

The competition is open to all individuals in the private sector or government who work in facilities located in the United States. Employees of nationally recognized private-sector standards-developing organizations are ineligible. In addition to showing how competitiveness can be promoted through the application of standardization practices, the paper should make an important contribution to furthering the development and understanding of standardization in government, commerce, and industry.

For copies of contest rules and entry forms, write to the National Standards Week Paper Competition, Standards Engineering Society, Box 2307, Dayton, Ohio 45401-2307. Papers should be received by the National Standards Week Committee no later than *June 15, 1992*.

New Report

'COMPETITIVENESS and TECHNOLOGY POLICY'

U.S. competitiveness in global markets and national technology policy constituted the theme of an IEEE workshop held in conjunction with the 1991 Engineering Societies Government Affairs Conference, under the auspices of the American Association of Engineering Societies. Moderated by Erich Bloch, former director of the National Science Foundation, the workshop examined the role that technology policy can and should play in advancing U.S. economic competitiveness. In the first of two panel sessions, invited speakers outlined industry perspectives on economic issues and needed incentives. In the second panel, Government speakers described current Federal strategies to promote technological competitiveness.

A 32-page summary report of the workshop, "Competitiveness and Technology Policy," has been released by the IEEE's Technology Policy Conference Committee. Copies are free on request to the IEEE's United States Activities Office, 1828 L St., N.W., Suite 1202, Washington, D.C. 20036.

HOW TO DEVELOP A STANDARD

The IEEE Standards Board has created an introductory videotape entitled "How To Develop a Standard." The tape is nearly 15 minutes long and was designed to be shown to groups as part of a meeting. The Standards department also maintains a list of speakers who are experienced in IEEE standards development and located throughout the United States.

For further information on speakers and a copy of the videotape and related meeting materials, contact Karen DeChino, 908-562-3802; fax, 908-562-1571; or CIRCLE #82 on the Reader Service Card.

COMPETING IN THE WORLD MARKETPLACE

IEEE United States Activities recently published *How the United States Can Compete in the World Marketplace*, a practical guide developed by the Committee on U.S. Competitiveness.

The 24-page booklet outlines several steps that the United States can take to regain its competitive edge, such as creating more funds for private capital investment; modifying Federal antitrust policies to conform with the current global market situation; investing in long-term manufacturing processes; employing managers with a good understanding of the technologies and economics of their businesses; incorporating engineering courses in product development, manufacturing technology, and systems engineering into school curricula; and instituting pre-competitive R&D geared toward supporting a product line rather than specific products. The booklet is available free of charge from the IEEE-USA Office in Washington, D.C.

To order, CIRCLE #83 on the Reader Service Card.

IEEE Member Opinion Survey

This publication is the result of the first worldwide IEEE member opinion survey. Such topics as employment, education levels, the use of computers in the workplace, and important issues for electrical engineers in the 1990s are included in the core section. U.S. and non-U.S. members were also sent questions about their particular needs. U.S. members were asked to rank the importance of various professional issues to the individual member and to the profession and the status of educational services in the United States. Non-U.S. members were asked about such matters as membership in other technical societies and attendance at IEEE conferences worldwide.

Product No.	Member	List
JH9992-9	$7.50	$19.95

To order, call 1-800-678-IEEE or 908-981-0060 outside the United States.

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS MAIL PERMIT NO. 885, PITTSFIELD, MA

POSTAGE WILL BE PAID BY ADDRESSEE

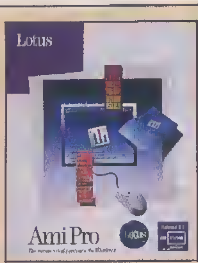
IEEE SPECTRUM

READER SERVICE MANAGEMENT DEPT.
PO BOX 5149
PITTSFIELD, MA 01203-9740

Software reviews

Technical word processing

by John R. Hines



***Ami Pro 2.0.** Lotus Development Corp. Windows- or NewWave-based word processor comes with a built-in equation editor and integrated tools for creating and editing charts, images, and tables. The version reviewed requires an IBM PC AT or compatible running MS DOS 3.0 or higher, 1 Mbyte of memory and 8 Mbytes of free disk space. US $495.*

Ami Pro 2.0 has the power of a full-featured word processor plus the unique features of a technical word processor. It includes not only a thesaurus, a dictionary, revision marking tools, and on-line help, but also, for instance, the ability to print text, tables, images, and equations at the same time. Four features make Ami Pro useful to engineers who have to create technical documents: a WIMP (windows, icons, mouse, and pull-down menus) user interface, WYSIWYG (what you see is what you get) Windows display, an equation editor, and a table tool.

The WIMP interface developed by Xerox Corp. simplifies word processing. Creating or modifying a document requires only a few point-and-click mouse movements and a few key strokes. At Honeywell Inc.'s Micro Switch Division engineers with no previous word-processing experience have created complex documents without training or assistance in less than a week.

The point-and-click interface is somewhat slow, however, so Lotus has supplied power user tools to reduce the number of mouse movements.

A WYSIWYG equation frame may be placed anywhere in a document, even inside a paragraph of standard text. An equation is built by pointing-and-clicking at one of several hundred special symbols in the editor menu and then copying the symbol into the right place in the equation box. The WYSIWYG display also saves the user from having to remember special key combinations or mentally translate ASCII characters on the display into symbols on paper.

The table function is another easy-to-use yet powerful feature. Tables may be inserted between paragraphs anywhere in a document. The tables do have one drawback, though: Ami Pro takes much longer to manipulate documents with tables than documents without tables.

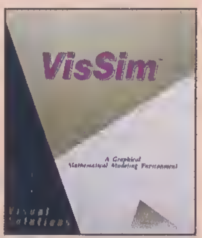
In short, Ami Pro can be used for any word processor task, no matter how complicated. It will merge text, equations, images, and tables into a single document that can be stored on a disk and, as laser-printed hard copy, can be published with no more ado. Ami Pro does everything an engineer or a scientist asks from a word processor. *Contact: Lotus Development Corp., 55 Cambridge Parkway, Cambridge, Mass. 02142; 617-577-8500; or* **circle 101.**

John R. Hines (M) is a silicon sensor engineer at Honeywell Inc.'s Micro Switch Division, Richardson, Texas.

A visual simulation tool

by David W. Barrett

Visual Solutions Inc. VisSim. *Software for block diagram modeling, simulation, and real-time monitoring and control of nonlinear dynamic systems. The version reviewed requires an IBM PC 286/386/486 or compatible, Microsoft Windows 3.0, at least 1M RAM, and a hard drive. US $1195. Unix versions available.*



VisSim is a block-diagram–based programming language. It combines an interactive graphical user interface with advanced mathematical methods of integration to produce models capable of simulating a broad range of physical systems. As a simulation platform, VisSim handles static, dynamic, linear, nonlinear, continuous, discrete, and hybrid systems. In addition, it can be connected to real-time data input and outputs (through analog-to-digital and digital-to-analog converter boards), creating a hardware-in-the-loop system.

The block diagram is VisSim's environment for simulation and it completely replaces the lines of code of conventional programming languages. The user creates a block diagram from the collection of building blocks supplied. Standard mathematical and Boolean functions, integration routines, time delays, table lookups, and maps are included in the package.

Because a large simulation can easily become crowded and incomprehensible, VisSim uses multiple-level block diagrams (compound blocks) to simplify the structure. A compound block may contain numerous functions but at the diagram's next higher level it appears as a single block having appropriate inputs and outputs.

Installing and learning to use the program is extremely easy. The manual or the on-line help is required only to identify input and output locations for the various blocks. Although the VisSim block diagrams are interpreted at simulation time, they operate at a reasonable speed. An example is a data reduction scheme I wrote using 15 integrators and numerous other mathematical operations to reduce 9000 time points of data to eight plots of two curves each. The entire task took 45 seconds on a 486 25-MHz PC. I also use the code as a data acquisition tool.

The VisSim software development kit (available separately) lets the user incorporate C or Fortran code blocks into the block diagram provided they are compiled with Microsoft compatible C or Fortran compilers. *Contact: Visual Solutions Inc., 487 Groton Rd., Westford, Mass. 01886; 508-392-0100; or* **circle 102.**

David W. Barrett is a principal systems research engineer with United Technologies Research Center, East Hartford, Conn.

COORDINATOR: Gadi Kaplan

Recent software

Ontos DB Release 2.2. Allows many users to simultaneously access and update specific objects in databases. For Sun 4 and Sun Sparcstation workstations running on Unix. US $25 000 to $150 000, depending on number of users and type of server. *Contact: Ontos Inc., Three Burlington Woods, Burlington, Mass. 01803; 617-272-8101; or* **circle 103.**

Executstat Release 3.0. Includes more than 150 analytical and statistical procedures. Requires DOS 2.0 or a later version, and 640K-bit RAM. Network support optional. US $375. *Contact: Strategy Plus Inc., 5 Independence Way, Princeton, N.J., 08540; 609-452-1345; or* **circle 104.**

EEs' tools & toys

Program tells how to acquire data by PC

A free software tool helps engineers and scientists select the hardware, software, and accessories needed to build a complete PC-based data acquisition system. The tool configures data acquisition systems for PC/XT/AT/EISA, PS/2, and Macintosh NuBus computers.

DAQ Designer, as it is called, asks questions about system requirements such as the type and number of analog and digital signals, the type and number of data acquisition sensors, and signal-conditioning needs. Then the software analyzes the user's answers and recommends specific plug-in data acquisition boards, signal-conditioning products, cable assemblies, and software packages that can be used to develop the desired data acquisition system. Naturally, the tool recommends only products made by National Instruments Corp., its maker, but the user can identify product types for cross-referencing them with other manufacturers' products.

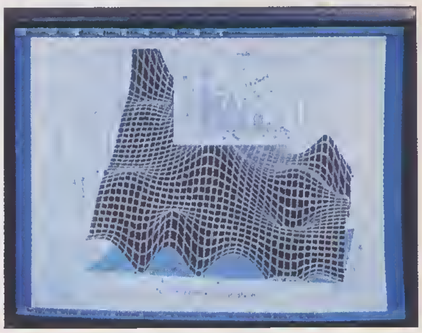
Once the user has identified all the system parameters and selected products, DAQ Designer creates a summary of what is needed. The system configuration can be saved to disk or printed using spreadsheet or word-processing software.

DAQ Designer requires a computer running DOS 3.0 or higher with a minimum 80286 processor, at least 640K of RAM, and a VGA monitor. *Contact: National Instruments Corp., 6504 Bridge Point Parkway, Austin, Texas 78730-5039; 512-794-0100; in the United States and Canada at 800-433-3488; telex, 756737 NAT INST AUS.; fax, 512-794-8411; or* **circle 105.**

COMPUTERS

Graphs in 3-D

A revised software package enables its users to create three-dimensional graphs. SigmaPlot 5.0 allows graphs to rotate interactively using a sparse matrix representation method that lets the user see the graph as it is adjusted. Researchers with *x,y,z* data can use the "interpolate mesh" command to convert their data to a 3-D mesh format. Other 3-D options include hidden-line removal, filled or unfilled polygons, frame lines, and backplanes with color. Labels for tick marks and axes can be rotated relative to the axis and text labels can be rotated at any angle.



Jandel Scientific Inc.'s SigmaPlot 5.0 generates 3-D graphs and merges the data from a collection of graphs to create a new one.

SigmaPlot 5.0 is an upgrade of the 4.1 version. Besides adding the 3-D capability, version 5.0 contains a file-merging command that takes a user-compiled list of SigmaPlot graphs and merges all the contents of each file onto the page. SigmaPlot 5.0 also re-sizes and scales the merged graphs if requested. Import options make SigmaPlot 5.0 compatible with most spreadsheet packages.

The new software retains complete compatibility with the earlier DOS version 4.0 and 4.1 files, as well as with SigmaPlot for Macintosh. SigmaPlot 5.0 for DOS costs US $495. *Contact: Jandel Scientific Inc., 2591 Kerner Blvd., San Rafael, Calif. 94901; 800-874-1888 or in California, call 415-453-6700; fax, 415-924-2850; or* **circle 106.**

INSTRUMENTATION

High-sample-rate scope

The four channels of a new portable oscilloscope from Hewlett-Packard Co. digitize simultaneously at one gigasample per second each. The high-sample-rate HP 54512B is an addition to the HP 54500 family of portable digitizing oscilloscopes. It also boasts 8-bit vertical resolution, 300-MHz repetitive bandwidth, and 8K bits of memory per channel.

The key benefit of providing a high sampling rate across all channels is that the instrument's 150-ps, single-shot timing accuracy is maintained when the user captures signals on more than one channel. This means that users can achieve higher system speeds because critical timing margins such as setup and hold times can be verified with a higher degree of accuracy than was previously possible.

The HP 54512B oscilloscope is priced at US $17 990. *Contact: Hewlett-Packard Co. Inquiries, 19310 Pruneridge Ave., Cupertino, Calif. 95014; 800-752-0900; or* **circle 107.**

GENERAL INTEREST

Ping-Pong-playing robots

Plans are under way for the First World Robot Ping-Pong contest—Robot '92—to be held in Hong Kong on Sept. 26–27. Each contestant must design and build his or her own robot and manipulate it with a remote control in a game of Ping-Pong against a similar robot.

The contest is being promoted by the International Micromouse Community, a group well-known for organizing micromouse contests around the world. In these events competitors guide electromechanical mice through a maze.

The a-mazing mice are still going strong. Upcoming micromouse contests will take place on July 7 in London at the Institution of Electrical Engineers; from Aug. 19 to 20 in Wellington, New Zealand, during Nelcon '92; and from Nov. 9 to 13 in Melbourne, Australia, during the IEEE Region 10 Conference—Tencon.

For the British contest, contact Kourosh Koodabandaloo at Bristol University, Bristol, England; for the New Zealand contest, contact Bart Provo, School of Electronic Engineering, Central Institute of Technology, Trentham, Wellington, New Zealand; and for the Australian contest, contact Sharon Smart at Macquarie University, School of Mathematics, Physics, Computing, and Electronics, New South Wales.

As for the Ping-Pong-playing newcomers, the Hong Kong contest organizers of Robot '92 have received enough in the way of funds to pay for the transportation of approximately 10 contestants. An application form plus a copy of the rules is available to anyone interested in participating. *Contact: Robin Bradbeer, City Polytechnic of Hong Kong, Department of Electronic Engineering, Tat Chee Avenue, Kowloon Tong, Hong Kong; (852) 788 7199; fax, (852) 788 7791.*

COORDINATOR: George Likourezos
CONSULTANT: Paul A.T. Wolfgang, Boeing Helicopters

PROFESSIONAL CONSULTING SERVICES

ADVERTISING RATES

1 Insertion—$320 12 Insertions—$3840

50% discount to IEEE members on three or more insertions.
If you are an IEEE member, please enclose your membership number with the order.
Copy cannot exceed 1-inch in depth. No product may be offered for sale. Advertising restricted to professional engineering and consulting services. No orders can be accepted by telephone; order and copy must be sent together.
For any further information and closing dates please contact:
Advertising Production, 212-705-7578

CONSULTING SERVICES

Editorial Offices: New York City 212-705-7555 San Francisco 415-282-3608 Washington, DC 202-544-3790

EDITORIAL CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Editorial Dept. Responsibility for the substance of articles published rests upon the authors, not the IEEE or its members. Letters to the editor may be excerpted for publication.
REPRINT PERMISSION. Libraries: Articles may be photocopied for private use of patrons. A per-copy fee (indicated after the code appearing at the bottom of the first page of each article) must be paid to the Copyright Clearance Center, 29 Congress St., Salem, Mass. 01970. *Instructors:* Isolated articles may be photocopied for noncommercial classroom use without fee. *Other copying or republication:* Contact: Editor, *IEEE Spectrum*.
ADVERTISING CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Advertising Dept., 212-705-7760. Also see Advertising Sales Offices listing on last page. The publisher reserves the right to reject any advertising.
COPYRIGHTS AND TRADEMARKS. IEEE Spectrum is a registered trademark owned by The Institute of Electrical and Electronics Engineers, Inc. EEs' Tools & toys, Faults & failures, Innovations, Legal aspects, Managing technology, Newslog, Program notes, Reflections, Speakout, Spectral lines, Spinoffs, Technically speaking, The engineer at large, and Whatever happened to? are trademarks of the IEEE.
GENERAL INQUIRIES: 1-800-678-IEEE; Headquarters: 345 East 47th St., New York, N.Y. 10017, 212-705-7900. *Tel. extensions at headquarters:* General Manager, 7910; Public Relations, 7369; Publishing Services, 7560. *At other locations:* Regional Activities, Section Services, Educational Activities, 908-981-0060, or write to IEEE Service Center, Box 1331, Piscataway, N.J. 08855; Membership Services, 908-981-0060; Professional Services, 202-785-0017; Technical Activities, 908-562-3900.

Scanning
The Institute

Quality teams improve member services

IEEE members and customers should start seeing a more responsive IEEE because of the Institute's adoption of the Total Quality Management (TQM) approach to its operations.

As a result, orders are being processed faster (on the average of three and one-half days after they are input to the system), the reject rate for processing payments for items like periodical subscriptions and membership renewals has been reduced, and the efficiency in crediting accounts has been increased.

In addition, a Customer Service Center was launched in February. Among the center's goals is to provide customers with "one-stop shopping." Now being set up, this service will allow customers or members to find out about things like membership, orders, and accounts receivable with just one phone call to a service representative.

Already produced is an inventory of the IEEE's many products and services. In the works is a new telephone directory for the Institute with listings based on who does what and what's done where; it includes a generic section indexed by function. Training programs to alert customer service representatives to marketing and product information are also under way.

IC R&D proposal

The National Advisory Committee on Semiconductors (NACS) recommended the undertaking of a cooperative R&D program to provide U.S. industry with 0.12-μm IC technology by the start of the 21st century.

The recommendation, called Micro Tech 2000, was proposed by a NACS task force of 90 U.S. semiconductor industry experts who called for R&D on several lithography alternatives, large wafers, advanced metrology, multilayer structures, new materials, computer simulation, and computer-integrated manufacturing.

The task force also proposed that 1G-bit static RAMs be developed by the year 2000, three years sooner than would be expected.

The recommendations are now being considered by the Semiconductor Industry Association (SIA), San Jose, Calif., which represents U.S. chip makers to the Government and the public. SIA was asked by NAS to take over responsibility for the plan, although NACS made no stipulations as to how it should be funded and organized.

Help for job-seekers

A new service has been implemented by IEEE United States Activities that may help job-hunters locate new positions. The service, called Peer II (for Professional Engineering Employment Registry II), succeeds the original Peer program, from which the IEEE withdrew last year.

Peer II is an electronic database that helps match job-seekers with companies needing workers. Each week the service scans and reports on job opportunities printed in classified advertisements in the news media of some 80 U.S. cities. It also taps into job openings made known at job fairs.

Because Peer I relied on company funding, monies dwindled as unemployment rose; with would-be workers knocking on their doors, employers no longer needed to pay Peer to find employees. In the new scheme, IEEE members who use the service will pay a nominal fee. *Contact: Marni Clark-Ivey, IEEE-USA, 1828 L St., N.W., Suite 1202, Washington, D.C. 20036; 202-785-0017.*

Coming
in Spectrum

WORKFORCE DIVERSITY. Most engineers entering the U.S. workforce in the next few decades will belong to minorities. So employers must be prepared to help the foreign-born adjust to U.S. corporate life, to assure women engineers of an upward career path, and to understand other groups' cultural orientations.

X-RAY OPTICS. X-ray lithography may employ low-power laboratory equipment as an X-ray source in combination with newly developed optical systems that bend and collimate X-rays.

ELECTROMAGNETIC RAILGUN. This developmental weapon utilizes the force that electric currents exercise on each other. Its power supply must deliver an electric pulse of tens of millions of joules in milliseconds.

WHAT *CASE* CAN DO. An expert on computer-aided software engineering (CASE) tools explains the prerequisites for success, likely benefits, and future prospects.

SOLID GROUND. Utilities are becoming expert on how state-of-the art computer and network electronics sometimes cause power-related failures. But steps can be taken by utilities' customers to prevent such problems in their facilities.

CARD-CARRYING DESIGNS. Flat, credit-card-sized modules for memory and peripheral functions are revolutionizing the design of notebook computers and augur an entirely new generation of portable equipment.

ADVERTISERS INDEX

Circle numbers on the Reader Service Card, opposite page 54, that correspond to the advertisers listed below. * Advertiser in North American edition. ** Advertiser in North American Exact edition.

MOMENTUM UNLOCKS INTEGRATED DSP SOLUTIONS

GET YOUR KEY FOR UNLOCKING POWERFUL EASY-TO-USE DSP SYSTEMS

Presenting the premier products from Momentum Data Systems

QEDesign™ gives you the key to designing the most bosic to the most complex digitol filters thot you'll ever need.

DSPworks™ helps you unlock DSP solutions with its reol-time doto ocquisition ond signal processing.

Momentum Code Generotors lock up your winning edge. Designed to creote highly optimized ossembly longuoge progroms with QEDesign.

Momentum products sove you time ond money with their menu-driven ond easy-to-use solutions. No long leorning curve or complex commonds to memorize.

Momentum is dedicoted to serving its customers by unlocking integroted DSP solutions. Whether its softwore only, or o combinotion of both hordwore ond softwore, Momentum has the key.

Momentum has softwore ond hordwore products ovoiloble on SUN SPARCstotions, Mocintosh, PC's ond Windows 3.0, ond offers complete soles, service, training ond consulting services.

Use the Momentum Key to unlock the best DSP solutions ovoiloble from one compony. Coll todoy for o complete demo kit.

714-557-6884

MOMENTUM
DATA SYSTEMS INC.

1520 Nutmeg Place, Suite 108, Costa Mesa, CA 92626, U.S.A.
Ph (714) 557-6884 Fax (714) 557-6969

Australia: SPA (Pty) Ltd. Tel: (3) 729-0995, Fox (3) 720-4298; **Denmark:** Assentoft Electronics, Tel 86 16 29 26, Fox 86 16 20 12; **France:** Excem, Tel (1) 47 52 13 44, Fax (1) 47 77 03 43; **Germany:** Electronic Tools, Tel (2102) 88010, Fax (2102) 880123; **India:** Signian Systems, Tel (842) 38085; **Italy:** CAD Itolio Srl, Tel (2) 617 2521, Fox (2) 612 0003 **Switzerland:** IDK, Tel (56) 27 27 77, Fax (56) 27 27 59; **United Kingdom:** Loughborough Sound Images Ltd., Tel (0509) 231843, Fox (0509) 262433; SSE Morketing, Tel (71) 387-1262, Fox (71) 388-0339. Product nomes are trodemorked to their respective companies.

Circle No. 11